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# **DRAFT**

## **Work Plan for an Engineering Evaluation/Cost Analysis in Support of the Intrinsic Remediation (Natural Attenuation) Option Tank 349 and Fire Protection Training Area 3**



**Offutt Air Force Base  
Omaha, Nebraska**

**Prepared For**

**Air Force Center for Environmental Excellence  
Brooks Air Force Base  
San Antonio, Texas**

**and**

**55 CES/CEVR  
Offutt Air Force Base  
Omaha, Nebraska**

**October 1994**

*AQMOI-04-0617*

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WORK PLAN FOR AN  
ENGINEERING EVALUATION/COST ANALYSIS  
IN SUPPORT OF THE INTRINSIC REMEDIATION  
(NATURAL ATTENUATION) OPTION  
TANK 349 AND FIRE PROTECTION TRAINING AREA 3

at

OFFUTT AIR FORCE BASE  
OMAHA, NEBRASKA

October 1994

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE  
BROOKS AIR FORCE BASE  
SAN ANTONIO, TEXAS

AND

55 CES/CEVR  
OFFUTT AIR FORCE BASE  
OMAHA, NEBRASKA

Prepared by:

Parsons Engineering Science, Inc.  
1700 Broadway, Suite 900  
Denver, Colorado 80290

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## SECTION 1

### INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering-Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct an engineering evaluation/cost analysis (EE/CA) for remediation of ground water contaminated with petroleum hydrocarbons at two sites [Tank 349 and Fire Protection Training Area 3 (FPTA-3)], located at Offutt Air Force Base (AFB) in Omaha, Nebraska. Offutt AFB will hereinafter be referred to as the Base. Several remedial options will be evaluated during the EE/CA, including free product removal; ground water extraction, treatment, and reinjection (i.e., pump and treat); air sparging; and natural contaminant attenuation (intrinsic remediation) with long-term monitoring. All hydrogeologic and ground water chemical data necessary to evaluate the various remedial options will be collected under this program; however, this work plan is oriented toward the collection of hydrogeologic data to be used as input into the Bioplume II ground water model in support of intrinsic remediation for restoration of fuel-hydrocarbon-contaminated ground water.

As part of the EE/CA, the Bioplume II modeling effort has three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to potential downgradient receptors; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The Bioplume II modeling effort for this site will involve completion of several tasks, which are described in the following sections.

This work plan was developed based on discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE), US Environmental Protection Agency (EPA), Nebraska Department of Environmental Quality (NDEQ), 55 Civil Engineering Squadron-Environmental Restoration Branch (CES/CEVR) personnel, and Parsons ES at a meeting conducted at the Base on August 15, 1994, on the statement of work (SOW) for this project, and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and 55 CES/CEVR.



## 1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide an EE/CA for remediation of ground water contamination at Tank 349 and FPTA-3. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with the EPA and Parsons ES to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in ground water, and to model this degradation using the Bioplume II numerical ground water model. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities to be performed in support of the EE/CA and the Bioplume II modeling effort. Field activities will be performed in two phases. Phase I focused on determining the extent of residual- and free-phase contamination, and was conducted in September 1994. Phase II will evaluate the extent of dissolved-phase contamination and will complete the characterization of the residual- and free-phase contamination.

Site characterization activities in support of the EE/CA include: 1) determination of preferential contaminant migration pathways; 2) cone penetrometer (CPT) and laser-induced fluorescence (LIF) testing; 3) monitoring point placement; 4) soil and ground water sampling; and 5) aquifer testing. The materials and methodologies required for collection of these data are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site obtained from widely accepted published literature will be used for model input. Sensitivity analyses will be conducted for the parameters which are known to have the greatest influence on the results of Bioplume II modeling, and where possible, the model will be calibrated using historical site data. Upon completion of the Bioplume II modeling, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will recommend the most appropriate ground water remedial technology based on available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and EE/CA report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There are two appendices to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for ground water samples. Appendix B contains a summary of existing soil and ground water analytical data from previous field investigation work.

## **1.2 BACKGROUND**

The Base occupies approximately 2,750 acres in eastern Sarpy County, Nebraska. It is bordered by the cities of Bellevue and Omaha to the north, the city of Papillion to the west, and agricultural land along the Missouri and Platte rivers to the east and south, respectively (Figure 1.1). The Base was originally established by the army in 1891 as Fort Crook, and was continuously operated by the army until transferred to the Air Force in 1948. From 1948 through 1992, the Base served as the headquarters for the Strategic Air Command (SAC). Since 1992, the Base has served as the Strategic Command (STRATCOM) Headquarters. The Base presently employs approximately 11,000 military and civilian personnel [Woodward-Clyde Consultants (W-C), 1992a].

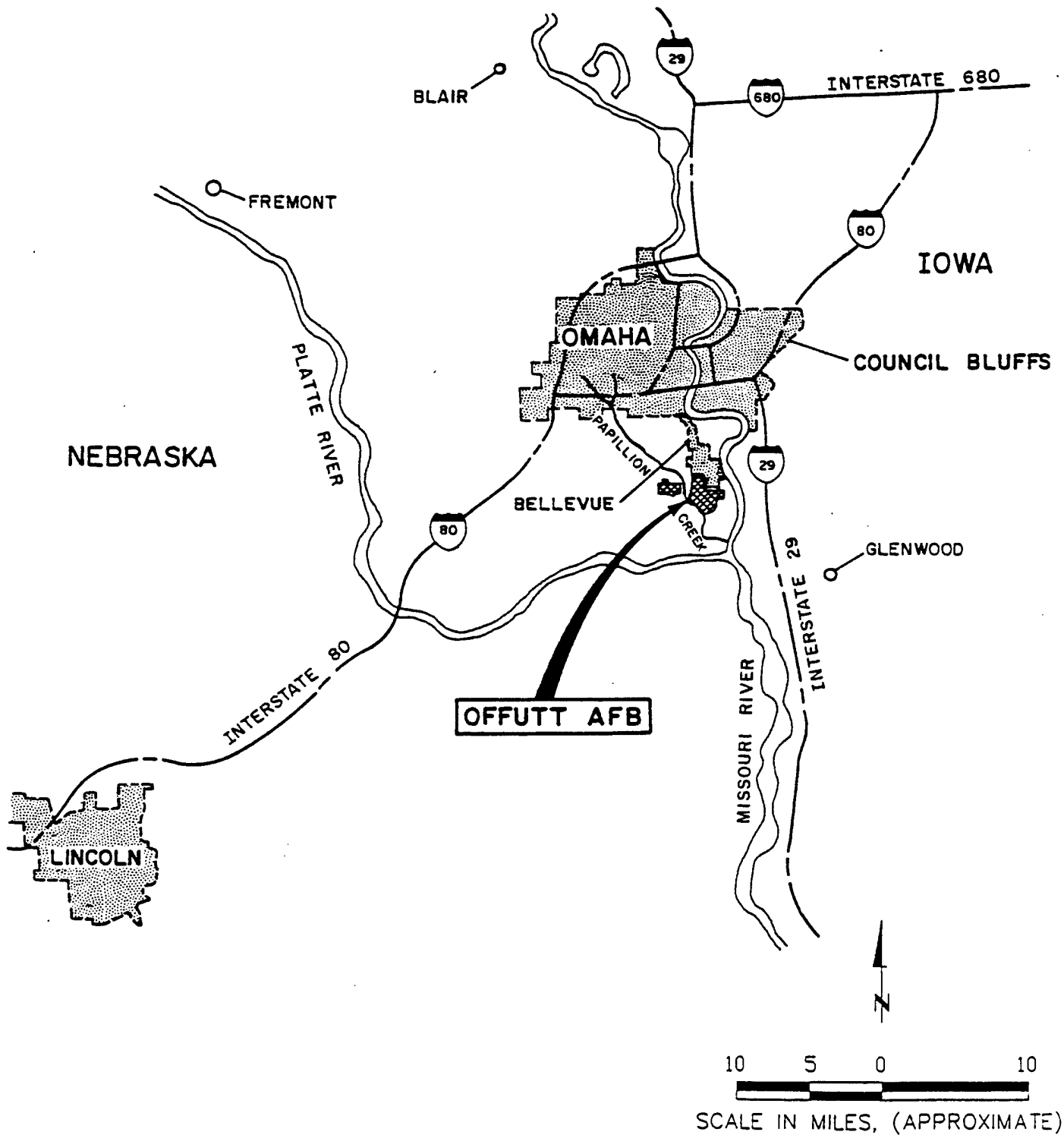
### **1.2.1 Tank 349 Site**

The Tank 349 site at Facility 6275 is the former location of three previously removed underground storage tanks (USTs). The site takes its name from Tank 349, an above-ground water tank. The site is located in the northern portion of the Base, along Peacekeeper Drive southwest of Building 304 (Figure 1.2). Two of the USTs formerly contained gasoline and were excavated in April 1993; the third UST formerly contained diesel fuel and was excavated in September 1993 [Terracon Environmental, Inc. (Terracon), 1994]. Base personnel identified the northeastern excavation as the former location of the two gasoline USTs. Soil contamination was observed at both excavation locations (Terracon, 1994).

Under the direction of NDEQ and the Base, Terracon conducted a ground water assessment from December 1993 through March 1994. The investigation included installation of 14 monitoring wells, collection of soil and ground water samples, field screening of soil samples and ground water samples, and laboratory analysis of ground water samples. The investigation defined a plume of dissolved-phase fuel hydrocarbons, and identified free-product at thicknesses of up to 2.2 feet in at least three of the monitoring wells near the point of release (Terracon, 1994). LIF testing for residual- and free-phase hydrocarbons was conducted by Parsons ES at the Tank 349 site during September 1994. The results of the LIF study generally supported the findings of the Terracon report with the exception that residual- and free-phase fuel hydrocarbons were identified over approximately the area that the previous investigation identified as dissolved-phase fuel hydrocarbons. Results of the LIF study will be presented in the forthcoming EE/CA report.

### **1.2.2 Fire Protection Training Area 3**

Fire protection training exercises were conducted at FPTA-3 from 1960 until the spring of 1990. The site is located west of County Road in the southeastern corner of the Base (Figure 1.3). Exercises were conducted approximately once per week from 1960 through 1974, using up to 2,000 gallons of waste fuels and solvents per training day. After 1974, exercises were conducted with approximately 300 gallons of jet fuel (JP-4) at a frequency of roughly twice per calendar quarter (ES, 1990a). The central training area at FPTA-3 is a bermed burn pit surrounding a model aircraft fuselage. The berm is roughly 4 feet higher than the interior of the burn pit, which is approximately 150 feet in diameter. Burn pit soils are stained and support very little vegetation. Disturbance of the surficial soils in the basin releases petroleum odors. A



**FIGURE 1.1**

**BASE LOCATION**

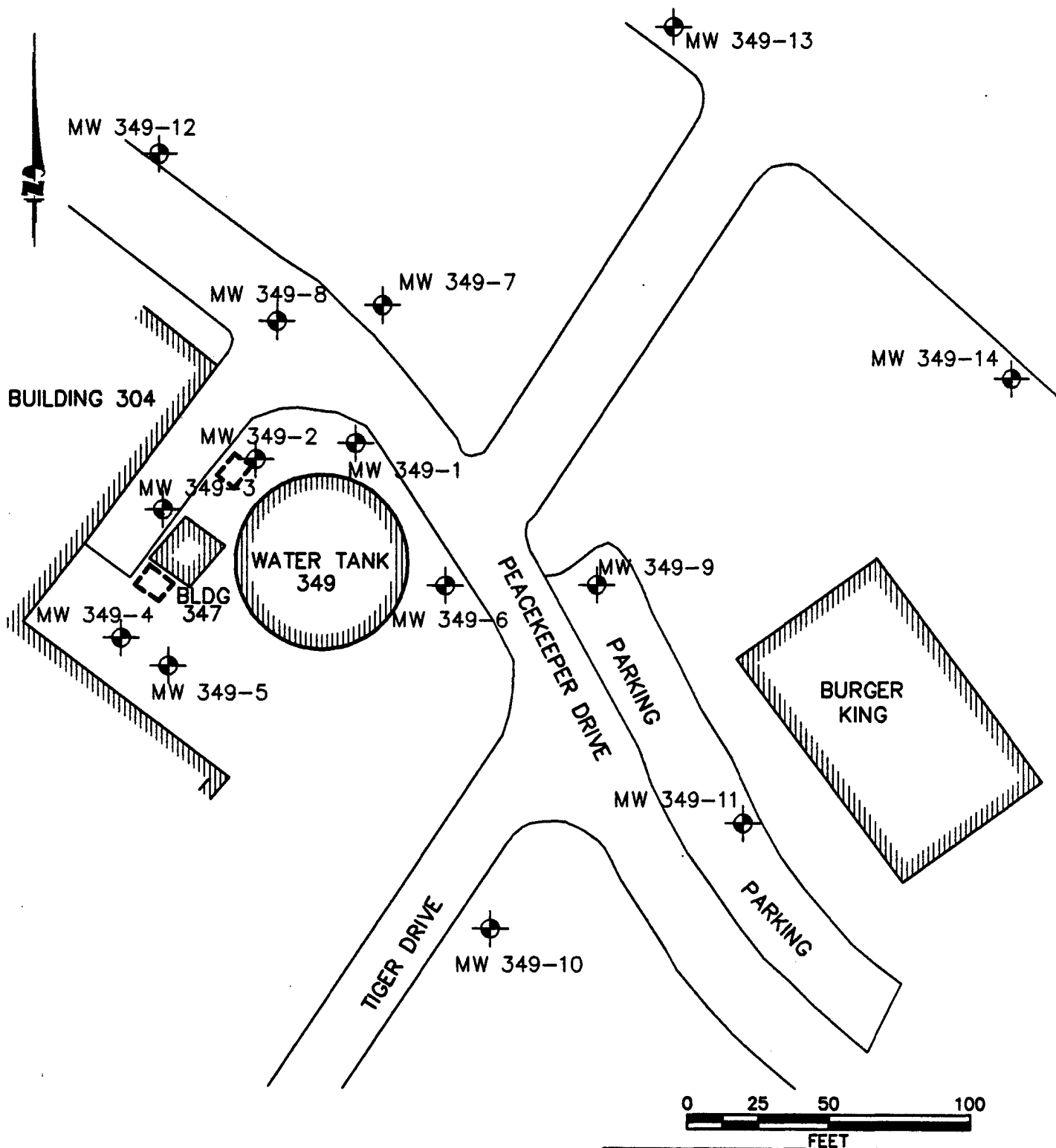
Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

Source: Woodward-Clyde Consultants, 1992

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# **LEGEND**



FORMER TANK EXCAVATION



MONITORING WELL

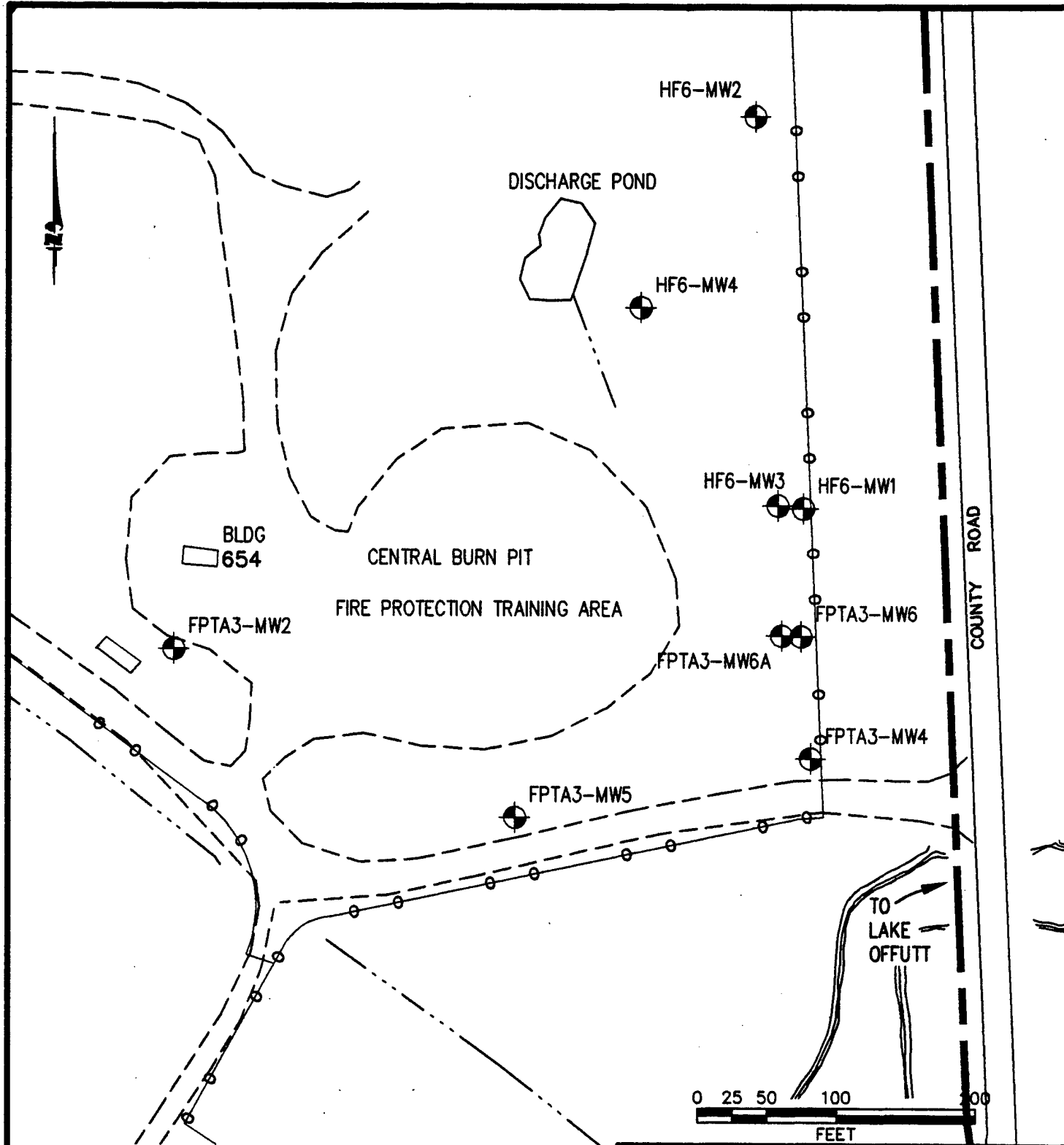
**FIGURE 1.2**

## **SITE LAYOUT TANK 349 SITE**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado



# **LEGEND**

- DIRT ROADS
- PAVED ROADS
- FENCES
- - - DRAIN PIPE
- ⊗ MONITORING WELL

**FIGURE 1.3**

## **SITE LAYOUT FIRE PROTECTION TRAINING AREA 3**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

drain pipe on the north side of the burn pit was used to discharge contaminated water from the burn pit to a pond north of the burn pit. Building 654, located west of the main burn pit, is a cinder block shell which appears to have also been used for training exercises. Historic aerial photographs are reported to indicate a fire training area where Building 654 currently stands (ES, 1990a). A second, smaller and less visibly contaminated burn pit is located between Building 654 and the drainage pond. This burn pit is surrounded by a 1.5 foot berm and is approximately 50 feet in diameter.

Under the Hazardous Waste Remedial Actions Program (HAZWRAP), investigations were conducted at FPTA-3 in 1988 and 1989 by ES (1990a) and reported in the *Site Inspection Report for Offutt Air Force Base*. Following the site inspection, B&V Waste Science and Technology Corporation (B&V) was contracted by the Air Force to perform a corrective measures study (B&V, 1990) and prepare a remedial action program for contaminated site soils (B&V, 1992); however, plans for soils remediation have not been implemented to date. During 1992, quarterly ground water monitoring was conducted by W-C as part of the Base ground water monitoring program. Limited LIF testing for residual- and free-phase hydrocarbons was conducted by Parsons ES at FPTA-3 during September 1994. The results of the LIF study identified hydrocarbon contamination and probable free-product in the main burn pit and in the vicinity of Building 654; however, the extent of the contamination was not determined. Results of the LIF study will be presented in the forthcoming EE/CA report.

## **SECTION 2**

### **DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT**

Existing site-specific data were reviewed and used to develop conceptual models of the ground water flow and contaminant transport regimes for the Tank 349 Site and FPTA-3. These conceptual models will allow efficient collection of additional data which will be used to support the Bioplume II modeling effort and to evaluate potential remediation technologies, including intrinsic remediation. Sections 2.1 and 2.2 present a synopsis of available site data. Section 2.3 presents the preliminary conceptual ground water flow and solute transport models that were developed based on these data.

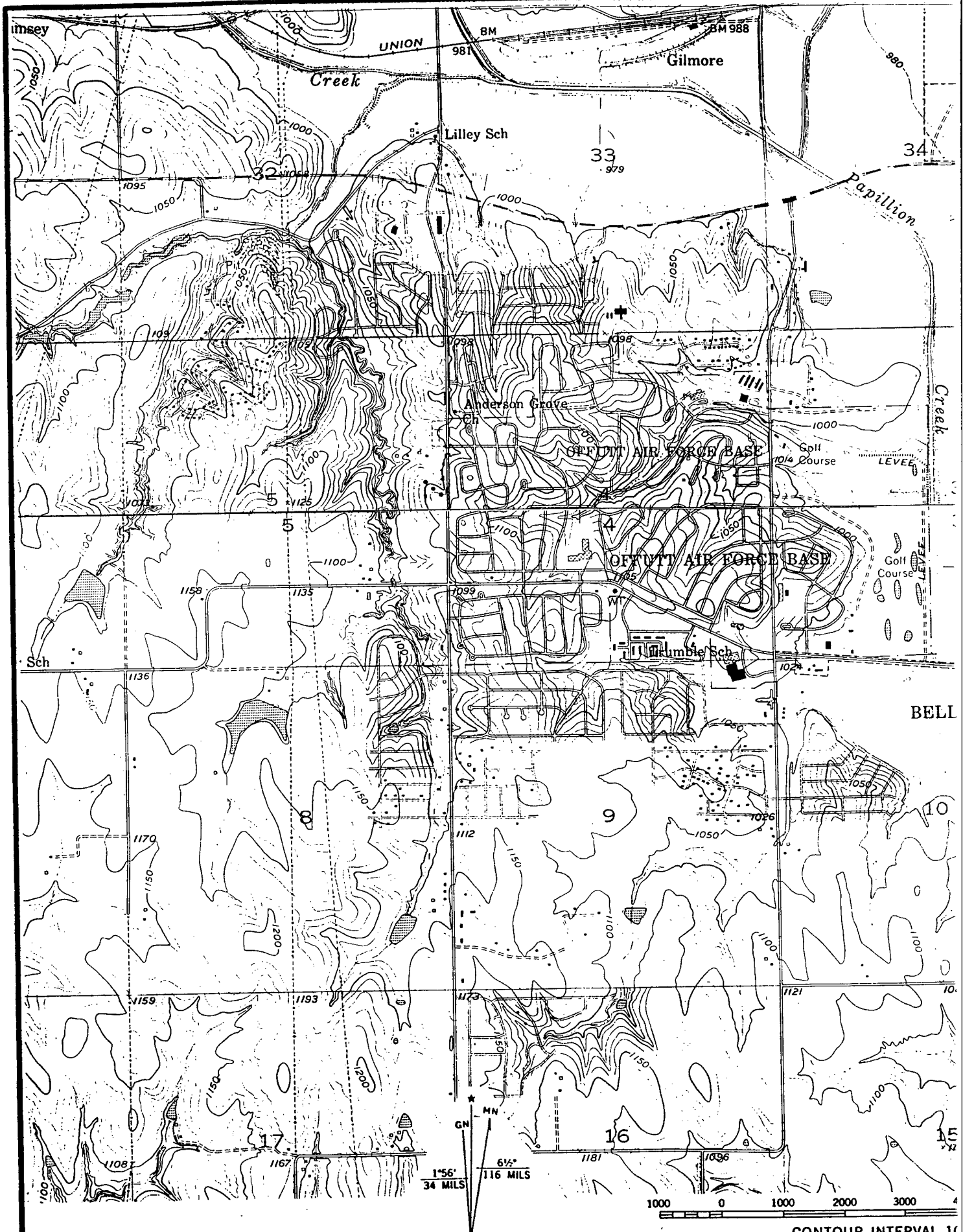
#### **2.1 DATA REVIEW**

The following sections were based upon review of data from the following sources:

- Groundwater Monitoring Program 1991-1992 (W-C, 1992b);
- Assessment Report -- Tank 349, Facility 6275 (Terracon, 1994);
- Corrective Measure Study -- Fire Protection Training Area 3 (B&V, 1990);
- Specifications -- Fire Protection Training Area 3 (B&V, 1992);
- Summary of Soil Sampling Investigation at FPTA-3 (ES, 1990b); and
- Results from CPT/LIF investigations conducted by Parson ES in September 1994.

##### **2.1.1 Topography, Surface Hydrology, and Climate**

The Base is located in the dissected till plains section of the Central Lowland Physiographic Province of the Interior Plains, a region characterized by large gently sloping plains, slight local relief, and relatively low altitudes of 500 to 2,000 feet above mean sea level (MSL). Base elevations range from approximately 960 to 1,140 feet MSL (USGS, 1984a and 1984b). A topographic map of the Base area is presented in Figure 2.1. The sites are situated on a dissected Pleistocene alluvial terrace remnant of the Missouri River with moderately sloping rolling hills (W-C, 1992b).



Source: US Geological Survey, 1984a and 1984b

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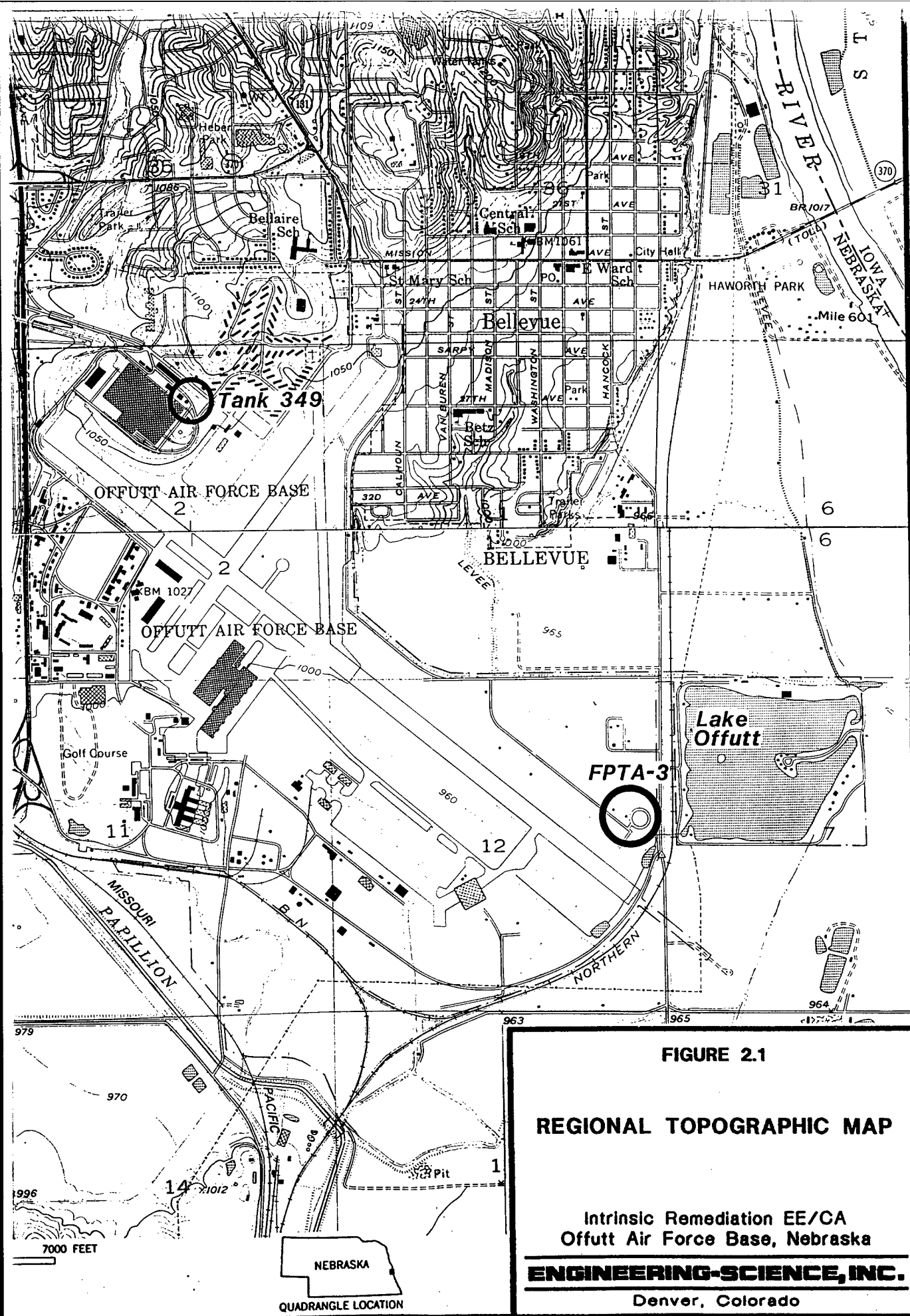
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Major surface water features in the area include the Missouri River, located 0.5 to 2 miles east of the Base boundary, and the Platte River, located approximately 3 miles south of the Base boundary. Papillion Creek flows between the Cape Hart Housing Area and the main body of the Base to its confluence with the Missouri River southeast of the Base. Lake Offutt occupies the southeast corner of the Base (Figure 2.1). At FPTA-3, surface water runoff discharges into Lake Offutt, located approximately 500 feet east of the site. A lake inlet is located only 60 feet southeast of the fence surrounding FPTA-3 (Figure 1.3). The discharge pond at FPTA-3 may still receive surface discharge from the main burn pit. Surface water at the Tank 349 Site is drained through storm sewers (Terracon, 1994).

The climate is continental, characterized by cold winters, hot summers, and moderate rainfall. Average daily maximum temperatures range from 29 degrees Fahrenheit (°F) in January to 87°F in July. Precipitation occurs primarily as slow, steady rainstorms during spring, as scattered thunderstorms (often with high wind) during late spring and summer, and as snow during the winter. The mean annual Base precipitation is approximately 31.9 inches, with about 75 percent of the annual precipitation occurring between April and September. The 1-year, 24-hour rainfall event is reported to be 2.5 inches (B&V, 1990).

## **2.1.2 Overview of Geology and Hydrogeology**

### **2.1.2.1 Regional Geology and Hydrogeology**

Regionally, bedrock consists of interbedded shale and limestone of Pennsylvanian age. In the rolling upland areas, bedrock is overlain by as much as 200 feet of glacial and periglacial deposits. The glacial deposits consist of thick sequences of clay-rich till with thin and thick interbeds of sand and gravel outwash. A mantle of periglacial loess at least 25 feet thick overlies most of the glacial till in the upland areas (W-C, 1992b).

Lowland areas are occupied by alluvial and glacial fluvial sediments that range in thickness from less than 10 feet near the upland areas to greater than 100 feet near the Missouri River. The glacial fluvial deposits consist of fine to coarse sand and gravel, grading upward to alluvial fine sand and silty sand and covered by up to 20 feet of alluvial organic silt and clay. In some areas of the Base, fill materials, typically loose sands, are present at thicknesses of up to 10 feet (W-C, 1992b).

Remnants of Pleistocene alluvial terraces occupy valley sides and former drainageways of major streams in eastern Nebraska. Most of these terraces are composed of fine-grained alluvium (fine sand and silt), and all of them are capped by Peorian loess. Much of the city of Bellevue and part of the Base occupy a dissected Pleistocene terrace remnant of the Missouri River (W-C, 1993).

The ground water surface generally reflects the surface topography. Hydraulic gradients in the upland areas are relatively steep where hydraulic conductivities are low and depth to ground water can exceed 50 feet. In lowland areas, hydraulic gradients

are relatively flat, hydraulic conductivities are higher, and the depth to ground water is frequently 10 feet or less. Base-wide hydraulic conductivities have been measured from 0.03 feet per day (ft/day) in shallow fill and alluvial clay/silt to 270 ft/day in deep glacial outwash sand. Hydraulic conductivities in the deeper ground water zones are nearly always higher than near the ground water surface. The highest measured shallow hydraulic conductivity was 9.5 ft/day in alluvial silty sand. Regionally, ground water flow is predominantly toward Papillion Creek and the Missouri River. Locally, ground water flow may be influenced by site features such as drainage ditches, paved surfaces, and buried utilities (W-C, 1992b).

#### **2.1.2.2 Tank 349 Geology and Hydrogeology**

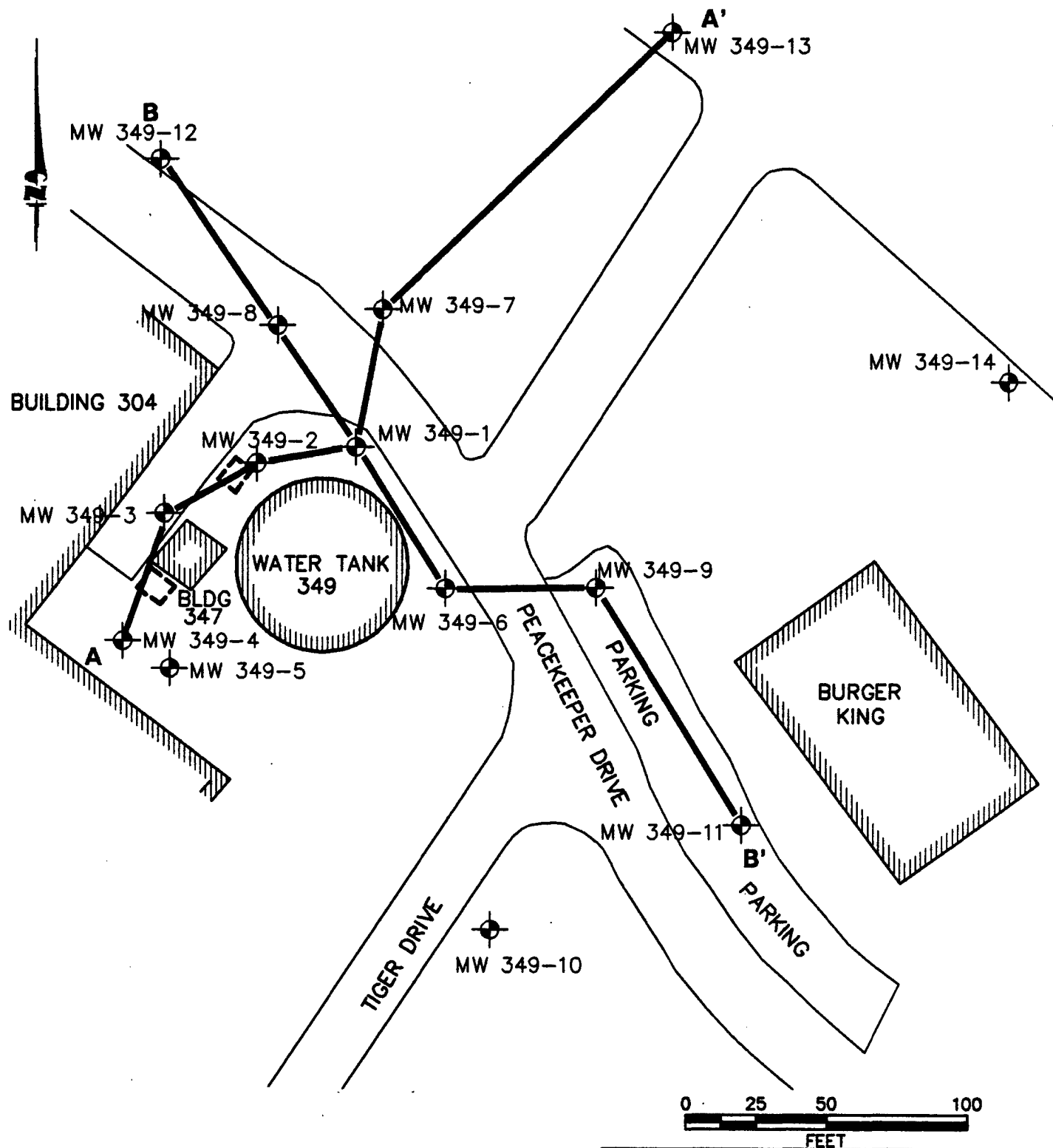
During the Tank 349 assessment, soils were logged from 14 boreholes completed as monitoring wells (Figure 2.2). Boreholes were 44 to 60 feet below ground surface (bgs) in depth. Hydrogeologic cross-sections are presented in Figures 2.3 and 2.4. The locations of the cross-sectional lines are shown on Figure 2.2.

Subsurface soils in the vicinity of the Tank 349 site consist of reddish-brown to brown clay with varying amounts of sand and/or gravel from ground surface to depths of up to 49.5 feet. In borehole MW349-14, a light-brown clay was observed over the bottom 5.5 feet of the borehole (49.5 to 55.0 ft bgs). At depths of greater than 36 feet, stringers of fine to very fine sand with thicknesses of less than 1 foot to approximately 18 feet were observed in 10 of the 14 boreholes (Terracon, 1994).

Ground water occurs at a depth of approximately 39 to 55 feet bgs in the vicinity of Tank 349. Ground water flow is toward the east based on ground water elevations measured on March 18, 1994 (Figure 2.5). Site hydraulic conductivity was estimated at 0.2 ft/day from a rising-head slug test performed on monitoring well MW349-5 (Terracon, 1994). Using a horizontal hydraulic gradient of 0.0023 foot per foot (ft/ft) and an estimated porosity of 0.25 for alluvial silty sand (W-C, 1992b), the estimated ground water flow velocity is approximately 0.7 foot per year (ft/year). Monitoring well construction details and ground water elevations for the Tank 349 Site are provided in Tables 2.1 and 2.2, respectively.

#### **2.1.2.3 FPTA-3 Geology and Hydrogeology**

Subsurface soils at FPTA-3 have been characterized from 5 soil boreholes sampled for laboratory analysis, 11 hand-auger boreholes sampled for laboratory analysis, 9 monitoring well boreholes, and 5 soil boreholes sampled for geotechnical analysis (Figure 2.6). The upper 1.5 to 10 feet of site soils have been described as clay, silt, and silty clay. These are underlain by poorly graded silty sand to a depth of at least 90 feet. The depth to bedrock has not been determined (B&V, 1990; ES, 1990b). None of the monitoring well borehole logs and 5 soil borehole logs were unavailable at the writing of this work plan. Boreholes with available logs had average depths of approximately 6 feet; therefore, hydrogeologic cross-sections could not be constructed. Monitoring well construction details are provided in Table 2.3.



# **LEGEND**



FORMER TANK EXCAVATION



MONITORING WELL

A—A' HYDROGEOLOGIC CROSS-SECTION

**FIGURE 2.2**

## **HYDROGEOLOGIC CROSS SECTION LOCATIONS TANK 349 SITE**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

NORTH  
A'

MW 349-13

SOUTH  
A

MW 349-7

MW 349-4 MW 349-3 MW 349-2 MW 349-1

ELEVATION  
IN FEET

1060

1040

1020

1000

0 40



Approximate Horizontal Scale  
(Feet)

# LEGEND

- INDICATES GROUNDWATER ELEVATION
- INDICATES BOTTOM OF BORING
- INDICATES WELL SCREEN INTERVAL
- SANDY LEAN CLAY
- LEAN CLAY
- FINE SANDY LEAN CLAY

## Notes:

Vertical exaggeration=2X

Stratigraphic boundaries and water level lines are based on interpolation between borings and monitoring wells.

Actual subsurface conditions may vary.

Groundwater elevations were measured on March 18, 1994.

FIGURE 2.3

## GENERALIZED HYDROGEOLOGIC CROSS SECTION A-A' TANK 349 SITE

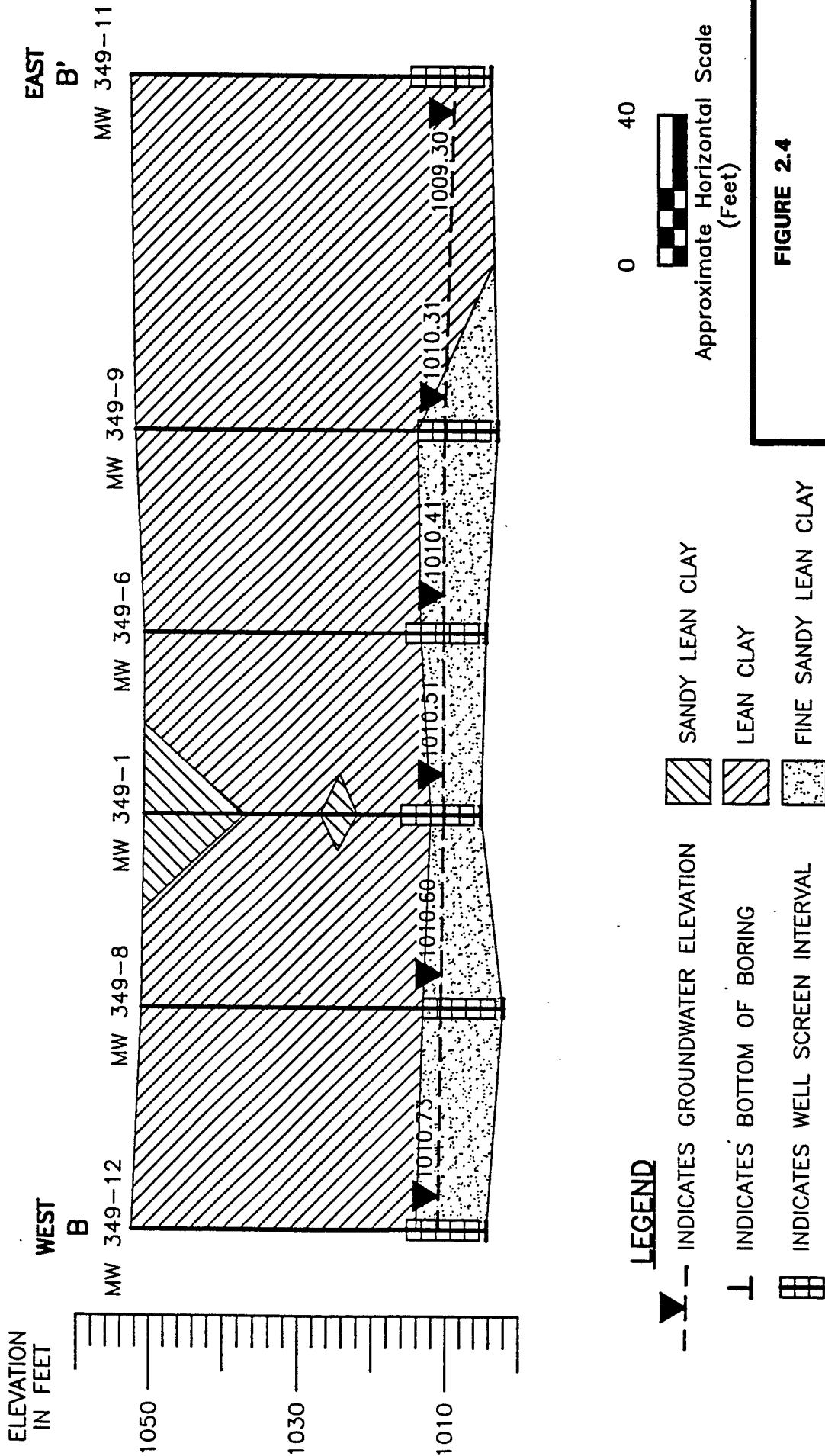
Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

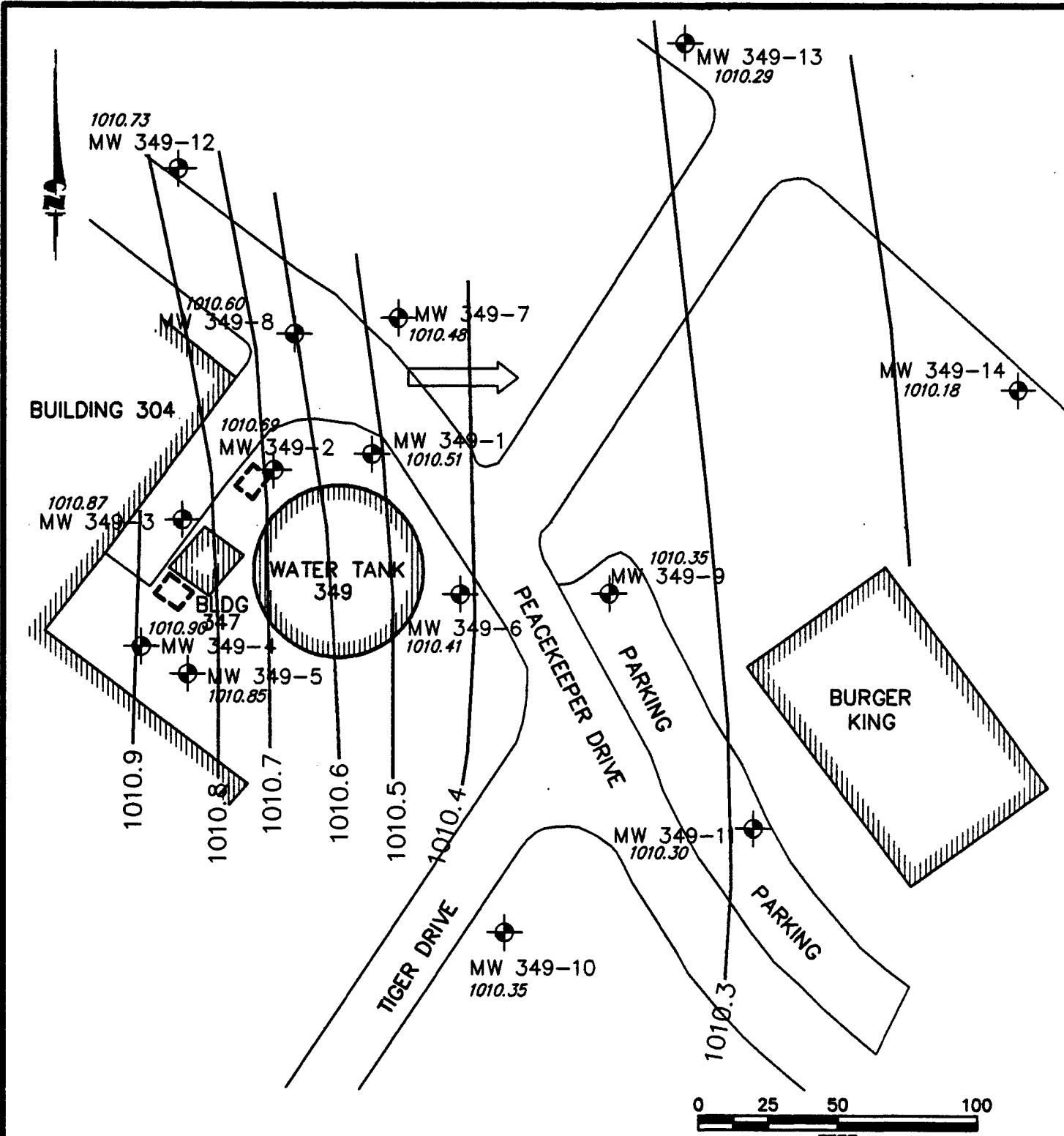
**ENGINEERING-SCIENCE, INC.**

Denver, Colorado





Source: Terracon, 1994.

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# **LEGEND**

-  FORMER TANK EXCAVATION
-  MONITORING WELL  
GROUND WATER ELEVATION  
(FEET MSL) MARCH 18, 1994
-  1010.8 — GROUND WATER CONTOUR (FEET MSL)  
CONTOUR INTERVAL = 0.1 FOOT
-  DIRECTION OF GROUND WATER FLOW

**FIGURE 2.5**

## **WATER TABLE MAP TANK 349 SITE (MARCH 1994)**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado



**TABLE 2.1**  
**SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS**  
**TANK 349 SITE**  
INTRINSIC REMEDIATION EE/CA  
OFFUTT AIR FORCE BASE, NEBRASKA

Well ID	Completion Date	Well Material	Elevation		Top of Filter Pack		Top of Well Screen		Bottom of Well Screen		Bottom of Well	
			TOC	GS	Depth	Elev	Depth	Elev	Depth	Elev	Depth	Elev
			ft MSL a/	ft MSL b/	ft bgs c/	ft MSL	ft bgs	ft MSL	ft bgs	ft MSL	ft bgs	ft MSL
MW 349-1	12/28/93	2" PVC	1050.34	1050.6	32.0	1018.6	34.0	1016.6	44.0	1006.6	44.0	1006.6
MW 349-2	12/15/93	2" PVC	1050.55	1050.9	38.0	1012.9	40.0	1010.9	50.0	1000.9	53.0	997.9
MW 349-3	1/4/94	2" PVC	1050.29	1050.6	32.0	1018.6	34.0	1016.6	44.0	1006.6	44.0	1006.6
MW 349-4	12/28/93	2" PVC	1050.85	1051.2	36.0	1015.2	38.0	1013.2	48.0	1003.2	48.0	1003.2
MW 349-5	12/27/93	2" PVC	1050.64	1050.9	36.0	1014.9	38.0	1012.9	48.0	1002.9	48.0	1002.9
MW 349-6	2/21/94	2" PVC	1050.20	1050.5	33.0	1017.5	35.0	1015.5	45.0	1005.5	45.0	1005.5
MW 349-7	2/21/94	2" PVC	1051.83	1052.2	36.0	1016.2	38.0	1014.2	48.0	1004.2	48.0	1004.2
MW 349-8	3/10/94	2" PVC	1050.65	1051.1	36.0	1015.1	38.0	1013.1	48.0	1003.1	48.0	1003.1
MW 349-9	3/10/94	2" PVC	1051.50	1052.0	36.0	1016.0	38.0	1014.0	48.0	1004.0	48.0	1004.0
MW 349-10	3/12/94	2" PVC	1050.67	1051.1	36.0	1015.1	38.0	1013.1	48.0	1003.1	48.0	1003.1
MW 349-11	3/11/94	2" PVC	1052.24	1052.8	36.0	1016.8	38.0	1014.8	48.0	1004.8	48.0	1004.8
MW 349-12	3/12/94	2" PVC	1052.17	1052.5	NA d/	NA	38.0 e/	1014.5 e/	48.0 e/	1004.5 e/	48.0	1004.5
MW 349-13	3/12/94	2" PVC	1064.44	1064.8	48.0	1016.8	50.0	1014.8	60.0	1004.8	60.0	1004.8
MW 349-14	3/11/94	2" PVC	1058.16	1058.5	NA	NA	45.0 e/	1013.5 e/	55.0 e/	1003.5 e/	55.0	1003.5

a/ Top of Casing; Feet Above Mean Sea Level  
b/ Ground Surface; Feet Above Mean Sea Level  
c/ Feet Below Ground Surface  
d/ Not Available  
e/ Presumed

**TABLE 2.2**  
**SUMMARY OF GROUND WATER LEVEL MEASUREMENTS**  
**TANK 349 SITE**  
**INTRINSIC REMEDIATION EE/CA**  
**OFFUTT AIR FORCE BASE, NEBRASKA**

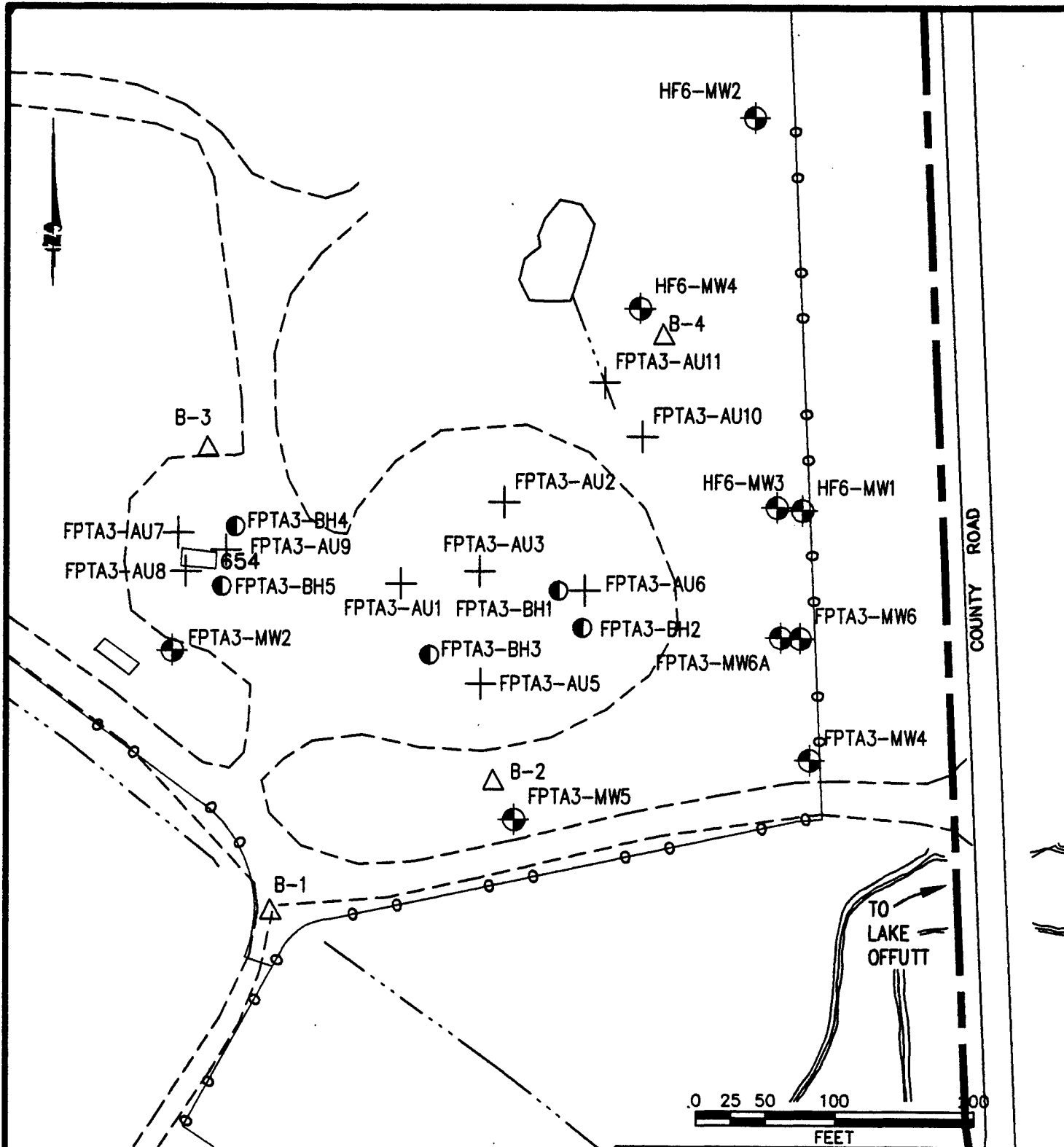
Sample Location	Sample Date	Easting	Northing	Datum Elevation (ft msl) b/	Depth to Water (ft TOC) c/	Depth to Product (ft TOC)	Product Thickness (feet)	Corr. Depth to Water a/ (ft TOC)	Corr. GW Elevation (ft msl)
MW 349-1	9/28/94	NA d/	NA	1050.34	41.08	39.03	2.05	39.54	1010.80
	3/18/94	NA	NA	1050.34	41.48	39.28	2.20	39.83	1010.51
MW 349-2	9/28/94	NA	NA	1050.55	40.40	39.51	0.89	39.73	1010.82
	3/18/94	NA	NA	1050.55	40.50	39.65	0.85	39.86	1010.69
MW 349-3	9/28/94	NA	NA	1050.29	36.85			36.85	1013.44
	3/18/94	NA	NA	1050.29	39.42			39.42	1010.87
MW 349-4	9/28/94	NA	NA	1050.85	39.48			39.48	1011.37
	3/18/94	NA	NA	1050.85	39.95			39.95	1010.90
MW 349-5	9/28/94	NA	NA	1050.64	39.44			39.44	1011.20
	3/18/94	NA	NA	1050.64	39.79			39.79	1010.85
MW 349-6	9/28/94	NA	NA	1050.20	41.89	39.07	2.82	39.78	1010.43
	3/18/94	NA	NA	1050.20	40.85	39.44	1.41	39.79	1010.41
MW 349-7	9/28/94	NA	NA	1051.83	41.73	41.10	0.63	41.26	1010.57
	3/18/94	NA	NA	1051.83	41.35			41.35	1010.48
MW 349-8	9/28/94	NA	NA	1050.65	40.11			40.11	1010.54
	3/18/94	NA	NA	1050.65	40.05			40.05	1010.60
MW 349-9	9/28/94	NA	NA	1051.50	-			-	-
	3/18/94	NA	NA	1051.50	41.15			41.15	1010.35
MW 349-10	9/28/94	NA	NA	1050.67	40.28			40.28	1010.39
	3/18/94	NA	NA	1050.67	40.32			40.32	1010.35
MW 349-11	9/28/94	NA	NA	1052.24	41.96			41.96	1010.28
	3/18/94	NA	NA	1052.24	41.94			41.94	1010.30
MW 349-12	9/28/94	NA	NA	1052.17	41.51			41.51	1010.66
	3/18/94	NA	NA	1052.17	41.44			41.44	1010.73
MW 349-13	9/28/94	NA	NA	1064.44	54.08			54.08	1010.36
	3/18/94	NA	NA	1064.44	54.15			54.15	1010.29
MW 349-14	9/28/94	NA	NA	1058.16	48.07			48.07	1010.09
	3/18/94	NA	NA	1058.16	47.98			47.98	1010.18

a/ Corrected Depth to Water = Measured Depth to Water - (0.75 x Product Thickness)

b/ Feet Above Mean Sea Level

c/ Feet Below Top of Casing

d/ Not Available



**LEGEND**

- DIRT ROADS
- PAVED ROADS
- FENCE
- - - DRAIN PIPE
- ⊙ MONITORING WELL
- + HAND AUGER
- BOREHOLE
- △ GEOPHYSICAL BOREHOLE

**FIGURE 2.6**

**SOIL SAMPLING LOCATIONS  
FIRE PROTECTION  
TRAINING AREA 3**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

**TABLE 2.3**  
**SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS**  
**FIRE PROTECTION TRAINING AREA 3**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUTT AIR FORCE BASE, NEBRASKA

Well ID	Completion Date	Well Material	Elevation		Top of Filter Pack		Top of Well Screen		Bottom of Well Screen		Bottom of Well	
			TOC ft MSL a/	GS ft MSL b/	Depth ft bgs c/	Elev ft MSL	Depth ft bgs	Elev ft MSL	Depth ft bgs	Elev ft MSL	Depth ft bgs	Elev ft MSL
HF6-MW2	9/8/88	2" PVC	964.82	962.96	4.8	958.2	4.8	958.2	19.8	943.2	22.3	940.7
HF6-MW4	8/1/91	2" PVC	966.14	963.68	4.0	959.7	5.0	958.7	19.0	944.7	20.0	943.7
FT3-MW1	9/1/88	2" PVC	965.77	963.90	77.0	886.9	79.5	884.4	89.0	874.9	89.0	874.9
FT3-MW2	9/6/88	2" PVC	964.98	964.30	2.7	961.6	4.7	959.6	19.7	944.6	22.3	942.0
FT3-MW3	9/6/88	2" PVC	964.37	963.90	3.0	960.9	4.0	959.9	19.5	944.4	22.0	941.9
FT3-MW4	9/6/88	2" PVC	966.17	964.45	3.5	961.0	7.0	957.5	22.0	942.5	22.0	942.5
FT3-MW5	9/25/88	2" PVC	966.43	964.33	2.5	961.8	5.5	958.8	20.5	943.8	23.5	940.8
FT3-MW6	NA /c	2" PVC	966.01	963.87	NA d/	NA	NA	NA	NA	NA	30.5	933.4
FT3-MW6A	11/17/89	2" PVC	966.01	963.83	18.0	945.8	20.0	943.8	35.0	928.8	37.0	926.8

a/ Top of Casing; Feet Above Mean Sea Level

b/ Ground Surface; Feet Above Mean Sea Level

c/ Feet Below Ground Surface

d/ Not Available

According to Base personnel and data from site monitoring wells, the depth to ground water at FPTA-3 fluctuates seasonally from within 3 to 4 feet of the surface during wet periods (usually late spring) to approximately 12 feet bgs during dry periods (late fall and winter) (B&V, 1990). Ground water flow is eastward toward the Missouri River with a flat gradient that ranges from 0.0004 to 0.002 ft/ft. A typical flow map constructed from March 1992 is presented in Figure 2.7. Historical ground water level measurements are provided in Table 2.4. Site hydraulic conductivities ranging 7.7 to 9.5 ft/day have been reported for FPTA-3 (W-C, 1992b). Using an average hydraulic conductivity of 8.6 ft/day, a gradient of 0.001 ft/ft, and an estimated porosity of 0.25 for alluvial silty sand (W-C, 1992b), the estimated ground water flow velocity is approximately 12.6 ft/year.

Prior to the construction of levees, the site lay within the 100-year flood plain of the Missouri River. The levees were designed to protect the area against a potential 500-year flood (B&V, 1990).

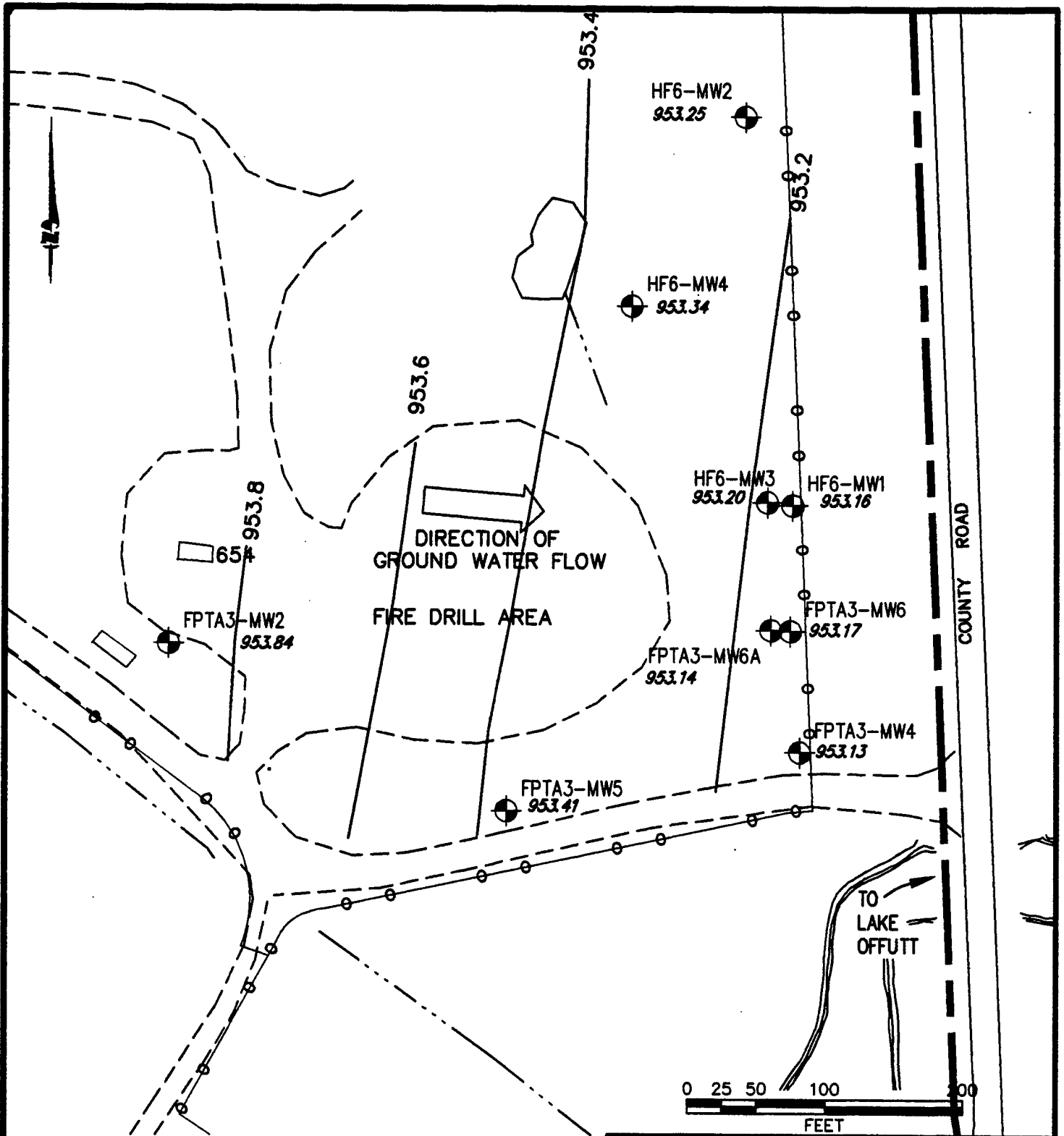
### **2.1.3 Soil Quality**

#### **2.1.3.1 Tank 349 Soil Sample Results**

Impacted soil was observed during removal of the three USTs in April and September 1993; however, soil samples were not collected for laboratory analysis during the 1993-1994 assessment at the Tank 349 Site (Terracon, 1994). Alternatively, soil samples were field screened with an organic vapor analyzer for the presence of volatile organic compounds (VOCs) in their headspace vapors. Soil samples from monitoring wells MW 349-1 and MW 349-2 had headspace measurements in excess of 50 parts per million, volume per volume (ppmv) from all soil samples collected at depths between 8 feet bgs and the borehole termination (44 and 53 feet bgs, respectively). All soil samples collected from 38 feet bgs or deeper from monitoring wells MW 349-6, MW 349-7, and MW 349-8 also had headspace measurements of greater than 50 ppmv. Several of the soil samples from these five wells had headspace measurements in excess of 1,000 ppmv; however, there was no apparent pattern to the distribution of soils with 1,000-ppmv headspace readings (Terracon, 1994). The lateral extent of soils with headspace concentrations in excess of 50 ppmv coincides with the area of residual- and free-phase fuel hydrocarbons identified during the September 1994 LIF investigations. Both LIF and soil headspace results coincide with the area of free-phase hydrocarbons detected in site monitoring wells (Figure 2.8). Results of the LIF investigations will be presented in the forthcoming EE/CA report.

#### **2.1.3.2 FPTA-3 Soil Gas and Soil Sample Results**

During investigations at this site, two soil gas surveys were conducted, and soil samples for laboratory analysis were collected during three separate field investigations. Fourteen sampling points were installed at FPTA-3 for the 1988 soil gas survey (ES, 1990a). Contamination was identified in the vicinity of the main burn pit, at Building 654, and northwest of the main burn pit at the suspected location of an



# **LEGEND**

- FENCE
- - - DIRT ROADS
- PAVED ROADS
- - - DRAIN PIPE
- ⊙ MONITORING WELL
- 953.84 GROUND WATER ELEVATION (FEET MSL)  
MARCH 1992
- 953.4— GROUND WATER CONTOUR (FEET MSL)  
CONTOUR INTERVAL = 0.2 FOOT

**FIGURE 2.7**

## **WATER TABLE MAP FIRE PROTECTION TRAINING AREA 3 (MARCH 1992)**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

**TABLE 2.4**  
**SUMMARY OF GROUND WATER LEVEL MEASUREMENTS**  
**FIRE PROTECTION TRAINING AREA 3**  
**INTRINSIC REMEDIATION EE/CA**  
**OFFUTT AIR FORCE BASE, NEBRASKA**

Sample Location	Sample Date	Easting	Northing	1991 Datum Elevation (ft msl) b/	Depth to Water (ft TOC) c/	Depth to Product (ft TOC)	Product Thickness (feet)	Corr. Depth to Water a/ (ft TOC)	Corr. GW Elevation (ft msl)
HF6-MW2	Aug-91	NA d/	NA	964.82	11.28			11.28	953.54
	Oct-91	NA	NA	964.82	11.89			11.89	952.93
	Dec-91	NA	NA	964.82	11.88			11.88	952.94
	Mar-92	NA	NA	964.82	11.57			11.57	953.25
	Apr-92	NA	NA	964.82	11.27			11.27	953.55
	May-92	NA	NA	964.82	10.24			10.24	954.58
	Aug-92	NA	NA	964.82	10.17			10.17	954.65
HF6-MW4	Aug-91	NA	NA	966.14	12.54			12.54	953.60
	Oct-91	NA	NA	966.14	13.13			13.13	953.01
	Dec-91	NA	NA	966.14	13.11			13.11	953.03
	Mar-92	NA	NA	966.14	12.80			12.80	953.34
	Apr-92	NA	NA	966.14	12.51			12.51	953.63
	May-92	NA	NA	966.14	11.43			11.43	954.71
	Aug-92	NA	NA	966.14	11.44			11.44	954.70
FT3-MW1	Aug-91	NA	NA	965.77	12.25			12.25	953.52
	Oct-91	NA	NA	965.77	12.89			12.89	952.88
	Dec-91	NA	NA	965.77	12.88			12.88	952.89
	Mar-92	NA	NA	965.77	12.61			12.61	953.16
	Apr-92	NA	NA	965.77	12.31			12.31	953.46
	May-92	NA	NA	965.77	11.23			11.23	954.54
	Aug-92	NA	NA	965.77	11.16			11.16	954.61
FT3-MW2	Aug-91	NA	NA	964.98	11.22			11.22	953.76
	Oct-91	NA	NA	964.98	11.79			11.79	953.19
	Dec-91	NA	NA	964.98	7.68			7.68	957.30
	Mar-92	NA	NA	964.98	11.14			11.14	953.84
	Apr-92	NA	NA	964.98	10.89			10.89	954.09
	May-92	NA	NA	964.98	9.85			9.85	955.13
	Aug-92	NA	NA	964.98	10.09			10.09	954.89
FT3-MW3	Aug-91	NA	NA	964.37	10.86			10.86	953.51
	Oct-91	NA	NA	964.37	11.48			11.48	952.89
	Dec-91	NA	NA	964.37	11.44			11.44	952.93
	Mar-92	NA	NA	964.37	11.17			11.17	953.20
	Apr-92	NA	NA	964.37	10.88			10.88	953.49
	May-92	NA	NA	964.37	9.75			9.75	954.62
	Aug-92	NA	NA	964.37	9.75			9.75	954.62

**TABLE 2.4 (Continued)**  
**SUMMARY OF GROUND WATER LEVEL MEASUREMENTS**  
**FIRE PROTECTION TRAINING AREA 3**  
**INTRINSIC REMEDIATION EE/CA**  
**OFFUTT AIR FORCE BASE, NEBRASKA**

Sample Location	Sample Date	Easting	Northing	1991 Datum Elevation (ft msl) b/	Depth to Water (ft TOC) c/	Depth to Product (ft TOC)	Product Thickness (feet)	Corr. Depth to Water a/ (ft TOC)	Corr. GW Elevation (ft msl)
FT3-MW4	Aug-91	NA	NA	966.17	12.65			12.65	953.52
	Oct-91	NA	NA	966.17	13.29			13.29	952.88
	Dec-91	NA	NA	966.17	13.29			13.29	952.88
	Mar-92	NA	NA	966.17	13.04			13.04	953.13
	Apr-92	NA	NA	966.17	12.74			12.74	953.43
	May-92	NA	NA	966.17	11.65			11.65	954.52
	Aug-92	NA	NA	966.17	11.60			11.60	954.57
FT3-MW5	Aug-91	NA	NA	966.43	12.79			12.79	953.64
	Oct-91	NA	NA	966.43	13.39			13.39	953.04
	Dec-91	NA	NA	966.43	13.37			13.37	953.06
	Mar-92	NA	NA	966.43	13.02			13.02	953.41
	Apr-92	NA	NA	966.43	12.72			12.72	953.71
	May-92	NA	NA	966.43	11.63			11.63	954.80
	Aug-92	NA	NA	966.43	11.72			11.72	954.71
FT3-MW6	Aug-91	NA	NA	966.01	12.49			12.49	953.52
	Oct-91	NA	NA	966.01	13.10			13.10	952.91
	Dec-91	NA	NA	966.01	13.10			13.10	952.91
	Mar-92	NA	NA	966.01	12.84			12.84	953.17
	Apr-92	NA	NA	966.01	12.55			12.55	953.46
	May-92	NA	NA	966.01	11.40			11.40	954.61
	Aug-92	NA	NA	966.01	11.42			11.42	954.59
FT3-MW6A	Aug-91	NA	NA	966.01	12.5			12.50	953.51
	Oct-91	NA	NA	966.01	13.12			13.12	952.89
	Dec-91	NA	NA	966.01	13.11			13.11	952.90
	Mar-92	NA	NA	966.01	13.87			13.87	952.14
	Apr-92	NA	NA	966.01	12.56			12.56	953.45
	May-92	NA	NA	966.01	11.45			11.45	954.56
	Aug-92	NA	NA	966.01	11.43			11.43	954.58

a/ Corrected Depth to Water = Measured Depth to Water - (0.75 x Product Thickness)

b/ Feet Above Mean Sea Level

c/ Feet Below Top of Casing

d/ Not Available



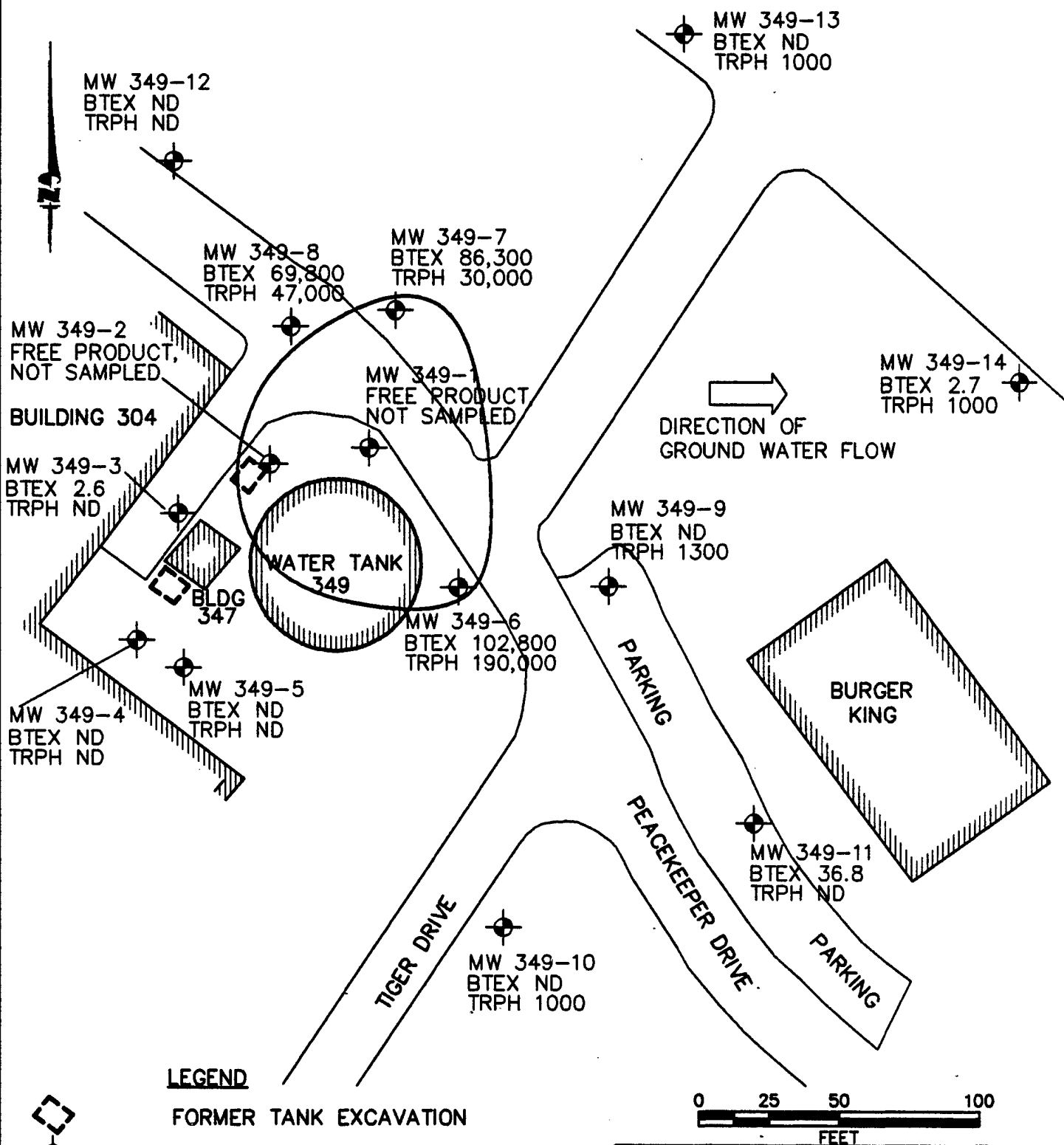


FIGURE 2.8

### FUEL CONSTITUENTS DETECTED IN GROUND WATER TANK 349 SITE

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

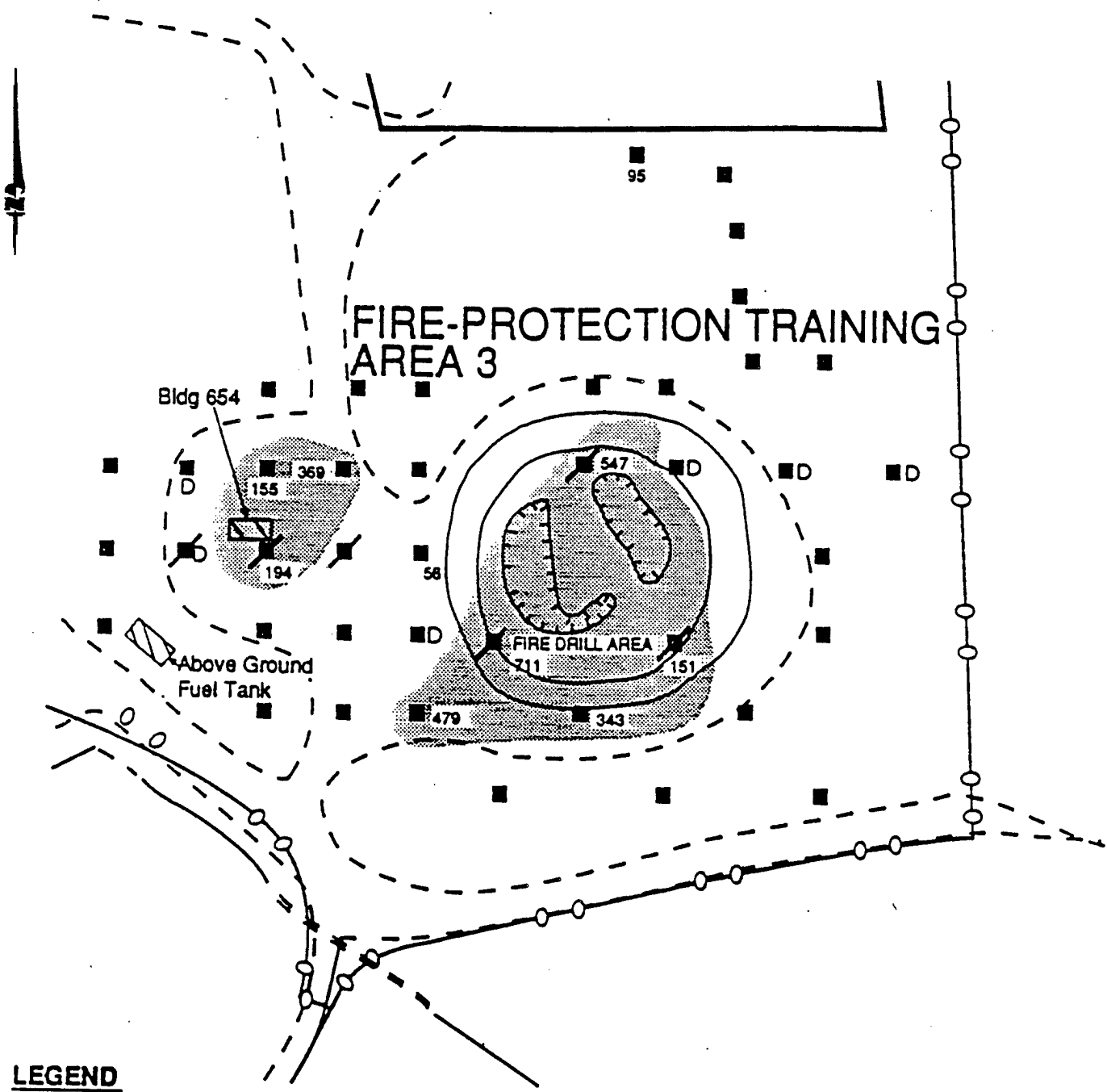
Denver, Colorado

historic burn pit. Benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds were detected in soil gas at all three areas, and chlorinated solvents were detected in the soil gas from the Building 654 sampling location. Soil gas samples were collected at an additional 41 locations in 1989. The survey identified two primary areas of BTEX contamination which are presented in Figure 2.9. Both the main burn pit and the Building 654 area had soil gas concentrations of BTEX in excess of 100 microgram per liter ( $\mu\text{g/L}$ ) (ES, 1990a). The highest detections of chlorinated solvents in soil gas were measured at the three locations of high BTEX contamination near Building 654, as identified in Figure 2.9. The most prevalent chlorinated solvents were cis-1,2-dichloroethene (DCE), 1,1,1-trichloroethane (TCA), and trichloroethene (TCE). Tetrachloroethene (PCE), trans-1,2-DCE, 1,1-DCE, and vinyl chloride were also detected in soil gas samples at these locations.

In general, soil sampling results confirm the results of the soil gas investigations. BTEX compounds were identified in soil samples collected from both the main burn pit and the Building 654 area (Figure 2.10). In addition, chlorinated solvents were detected in samples collected from near Building 654. Table 2.5 summarizes the detected BTEX and chlorinated solvent analytical results. The highest BTEX concentrations were identified from hand auger locations 1 and 3 at 387,000 and 182,000 micrograms per kilogram ( $\mu\text{g/kg}$ ), respectively. Both boreholes were augered in the main burn pit. Hand auger locations 3 and 5 were also located in the center of the main burn pit; however, the laboratory reported BTEX concentrations below detection limits. The lack of detected BTEX contamination is attributed to over-dilution of the samples by the laboratory prior to analysis which resulted in elevated detection limits. At hand auger locations 3 and 5, no single BTEX constituent was detected above 16,000  $\mu\text{g/kg}$  (ES, 1990b).

The highest concentrations of chlorinated solvents were detected in soil samples from boreholes 4 and 5, which are both situated near Building 654. Detected chlorinated solvents included 1,1-dichloroethane (DCA), 1,2-DCA, 1,2-DCE (total), PCE, 1,1,1-TCA, and TCE. A 430  $\mu\text{g/kg}$  detection of 1,2-DCE (total) from borehole 4 was the highest detected chlorinated solvent concentration. A single detection of TCE (134  $\mu\text{g/kg}$ ) was also detected in a soil sample at borehole 2, located in the main burn pit. In borehole samples chlorinated solvents were analyzed by method SW8010; however, in hand auger samples chlorinated solvents and BTEX compounds were analyzed together using method SW8240. As the main burn pit was primarily investigated with hand auger location, it is possible that chlorinated solvents are present throughout the main burn pit but have not been detected as a result of sample dilutions required for the very large concentrations of BTEX compounds. The sample dilutions result in correspondingly higher detection limits for chlorinated solvents as well as BTEX compounds (ES, 1990a).

Total BTEX was detected at a concentration of approximately 1,140  $\mu\text{g/kg}$  in a sediment sample collected from the existing discharge pond. Soil sampling has not identified BTEX contamination beyond the confines of the pond (ES, 1990a).



# **LEGEND**

- Soil Gas Sampling Point with BTEX not Detected
- D Soil Gas Sampling Point with Concentration of BTEX > 1ug/L
- 155 ■ Soil Gas Sampling Point with Concentration of BTEX > 5ug/L
- 711 ■ Soil Profile (Maximum Concentration Noted for Profile Point)
- Distribution of BTEX in Concentrations Greater than 100 ug/L

0 25 50 100 200  
FEET

**FIGURE 2.9**

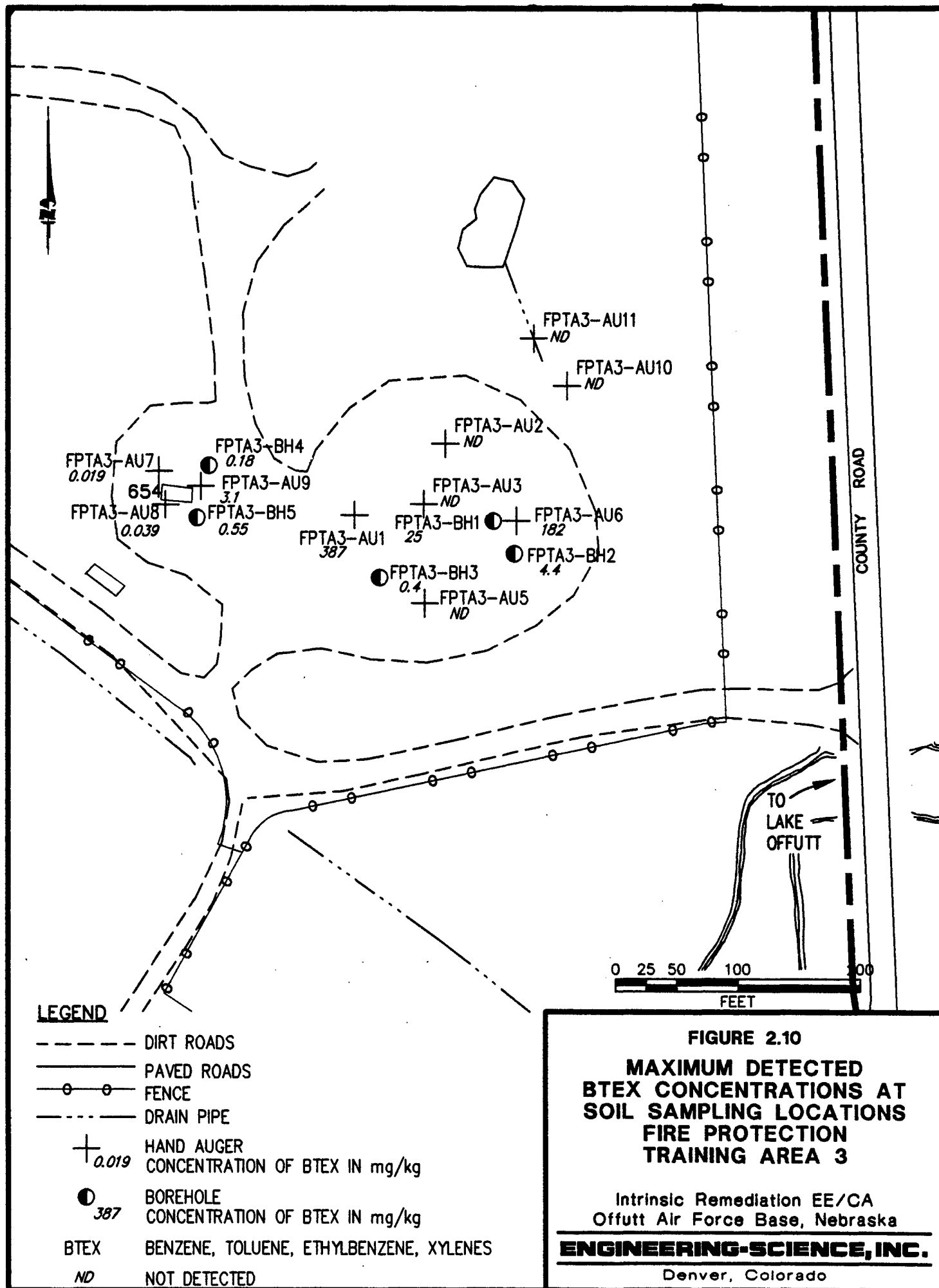
## **DISTRIBUTION OF BTEX IN SOIL GAS FIRE PROTECTION TRAINING AREA 3**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

Source: Engineering-Science, 1990a



**TABLE 2.5**  
**SUMMARY OF DETECTED FUEL CONSTITUENTS AND CHLORINATED SOLVENTS IN SOIL SAMPLES**  
**FIRE PROTECTION TRAINING AREA 3**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUTT AIR FORCE BASE, NEBRASKA

Analyte	FPTA3-BH1		FPTA3-BH2		FPTA3-BH3		FPTA3-BH4		FPTA3-BH5		FPTA3-MW1		FPTA3-AU1		FPTA3-AU2		FPTA3-AU3		FPTA3-AU5	
	2'	5'	8'	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	12'	2'	4'	2'	4'	2'	4'	2'	4'	2'	6'
<b>Volatiles Organics (SW5030/SW8240) (ug/kg)</b>																				
Benzene	2,800	- a/	-	-	15	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toluene	940	-	-	1,060	76	71	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	3,200	-	-	760	17	140	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Xylenes	18,000	380	-	2,600	68	320	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	58	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	69	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethene (total)	-	-	-	-	430	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	-	-	-	134	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Semivolatile Organics (SW3550/SW8270) (ug/kg)</b>																				
Naphthalene	1,800	750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Methylnaphthalene	1,600	2,800	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Petroleum Hydrocarbons</b>																				
SW3550/E418.1 (mg/kg)	15,000	910	1,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil samples without detected organics:  
 FPTA3-SB1 10'  
 FPTA3-MW1 6' and 9'  
 FPTA3-MW2 6' and 9'  
 FPTA3-MW3 6' and 9'  
 FPTA3-MW4 6', 9', and 12'  
 FPTA3-MW5 6' and 9'

a/ Not detected  
 b/ Not analyzed  
 Source: ES (1990a and 1990b)

**TABLE 2.5 (Continued)**  
**SUMMARY OF DETECTED FUEL CONSTITUENTS AND CHLORINATED SOLVENTS IN SOIL SAMPLES**  
**FIRE PROTECTION TRAINING AREA 3**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUTT AIR FORCE BASE, NEBRASKA

Analyte	FPTA3-AU6			FPTA3-AU7			FPTA3-AU8			FPTA3-AU9			FPTA3-AU10			FPTA3-AU11		
	2'	4'	2'	6'	10'	2'	6'	10'	2'	6'	10'	2'	6'	10'	2'	6'	10'	
Volatile Organics (SW5030/SW8240) (ug/kg)																		
Benzene	-	-	- a/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Toluene	-	-	10	64	19	33	39	33	1,200	-	-	-	-	-	-	-	-	
Ethylbenzene	-	-	-	-	-	-	-	-	700	-	-	-	-	-	-	-	-	
Xylenes	-	-	-	-	-	-	-	-	1,200	1,140	1,530	-	-	-	-	-	-	
1,1-Dichloroethane	-	-	6	23	21	-	-	-	-	-	-	-	-	-	-	-	-	
1,2-Dichloroethane	-	-	65	200	160	-	16	12	-	-	-	5	-	-	-	-	-	
1,2-Dichloroethene (total)	-	-	4	16	8	-	4	3	-	-	-	4	-	-	-	-	-	
1,1,1-Trichloroethane	-	-	58	170	89	9	23	18	5,200	-	480	-	-	-	-	-	-	
Trichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Tetrachloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Semivolatile Organics (SW3550/SW8270) (ug/kg)																		
Naphthalene	-	1,300	-	-	-	-	-	-	-	210	-	-	97	1,600	-	-	-	
2-Methylnaphthalene	4,900	2,000	-	-	-	-	-	-	-	470	-	-	250	11,000	350	-	-	
Petroleum Hydrocarbons																		
SW3550/E418.1 (mg/kg)	NA	NA	NA b/	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Soil samples with detected organics other than fuel constituents or chlorinate solvents

FPTA3-SB1 11' (Acetone) a/ Not detected

FPTA3-AU2 2' (Methylene chloride, Di-n-butylphthalate) b/ Not analyzed

FPTA3-AU5 2' (Methylene chloride, Acetone, Di-n-butylphthalate) Source: ES (1990a and 1990b)

FPTA3-AU10 6' (Methylene chloride, acetone)

FPTA3-AU11 2' (Methylene chloride, acetone, bis(2-Ethylhexyl)phthalate)

## **2.1.4 Ground Water Quality and Chemistry**

### **2.1.4.1 Tank 349 Ground Water Sample Results**

Ground water samples from 12 of the 14 monitoring wells were collected and analyzed for BTEX and total recoverable petroleum hydrocarbons (TRPH) during the Tank 349 assessment. Ground water samples were not collected from MW 349-1 and MW 349-2 because free-phase product was observed (Terracon, 1994). Total BTEX and TRPH concentrations are presented on Figure 2.8. Analytical results are summarized in Table 2.6.

The highest total BTEX and TRPH concentrations (102,800 µg/L and 190,000 µg/L, respectively) were detected in the ground water sample collected from MW 349-6, located approximately 80 feet downgradient of the tank excavation area. Of the sampled wells, MW 349-6 is the closest well downgradient from the excavation area. Monitoring wells MW 349-1 and MW 349-2 are the downgradient wells closest to the northeastern tank excavation; however, they were not sampled due to the presence of free-phase product (Terracon, 1994). Free product has also been observed in monitoring wells MW 349-6 and MW 349-7; however, these wells were sampled (Terracon, 1994). There are no wells between the southwestern tank excavation and monitoring well MW 349-6.

Leakage from the USTs removed from the northeastern excavation is the suspected source of hydrocarbon contamination. Interpretation of the extent of dissolved and free-phase hydrocarbons places this excavation at the head of the plume. The free-phase hydrocarbon plume has an estimated extent of 120 feet downgradient (to the east) and 70 feet to the north and south of the source (Figure 2.8).

Free-phase hydrocarbons have been identified at thicknesses of 2.2 feet in MW 349-1 and 0.85 feet in MW 349-2. A free-phase thickness of 1.4 feet was also reported for a third location in the assessment report (Terracon, 1994); however, the text, tables, and figures in the report do not agree on whether the product was detected in MW 349-6 or MW 349-7. Oil/water interface measurements performed during September 1994 identified free-phase hydrocarbons at thicknesses of 0.6 to 2.8 feet in wells MW 349-1, -2, -6, and -7 (Table 2.2).

### **2.1.4.2 FPTA-3 Ground Water Sample Results**

Ground water samples were collected and analyzed at FPTA-3 as a part of the Base site inspection (SI) and during the 1991-1992 quarterly ground monitoring program at the Base. The average 1992 quarterly ground water results for total BTEX and total chlorinated solvents are presented on Figure 2.11. A summary of all VOC results is provided in Table 2.7. BTEX compounds have been detected in ground water from only three wells, FPTA3-MW2, FPTA3-MW6A, and HF6-MW4. The highest BTEX concentrations have consistently been detected in ground water samples from HF6-MW4, which lies approximately 50 feet downgradient of the discharge pond. The

**TABLE 2.6**  
**SUMMARY OF GROUND WATER ANALYTICAL RESULTS**  
**TANK 349 SITE**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUTT AIR FORCE BASE, NEBRASKA

Analyte	Well Number				
	MW 349-1	MW 349-2	MW 349-3	MW 349-4	MW 349-5 MW 349-6 MW 349-7
Aromatic Volatile Organics (SW8020) (ug/L)					
Benzene	NA a/	NA	- b/	-	43,000 32,000
Toluene	NA	NA	-	-	3,800 3,300
Ethylbenzene	NA	NA	-	-	42,000 34,000
Xylenes	NA	NA	2.6	-	14,000 17,000
Petroleum Hydrocarbons					
SW3510/E418.1 (mg/L)	NA	NA	-	-	190,000 40,000

Analyte	Well Number				
	MW 349-8	MW 349-9	MW 349-10	MW 349-11	MW 349-12 MW 349-14
Aromatic Volatile Organics (SW8020) (ug/L)					
Benzene	21,000	-	-	2.5	-
Toluene	3,800	-	-	4.3	-
Ethylbenzene	31,000	-	-	13	-
Xylenes	14,000	-	-	17	2.7
Petroleum Hydrocarbons					
SW3510/E418.1 (mg/L)	47,000	1,300	-	-	-

a/ Not analyzed.

b/ Not detected.

Source: Terracon, 1994.



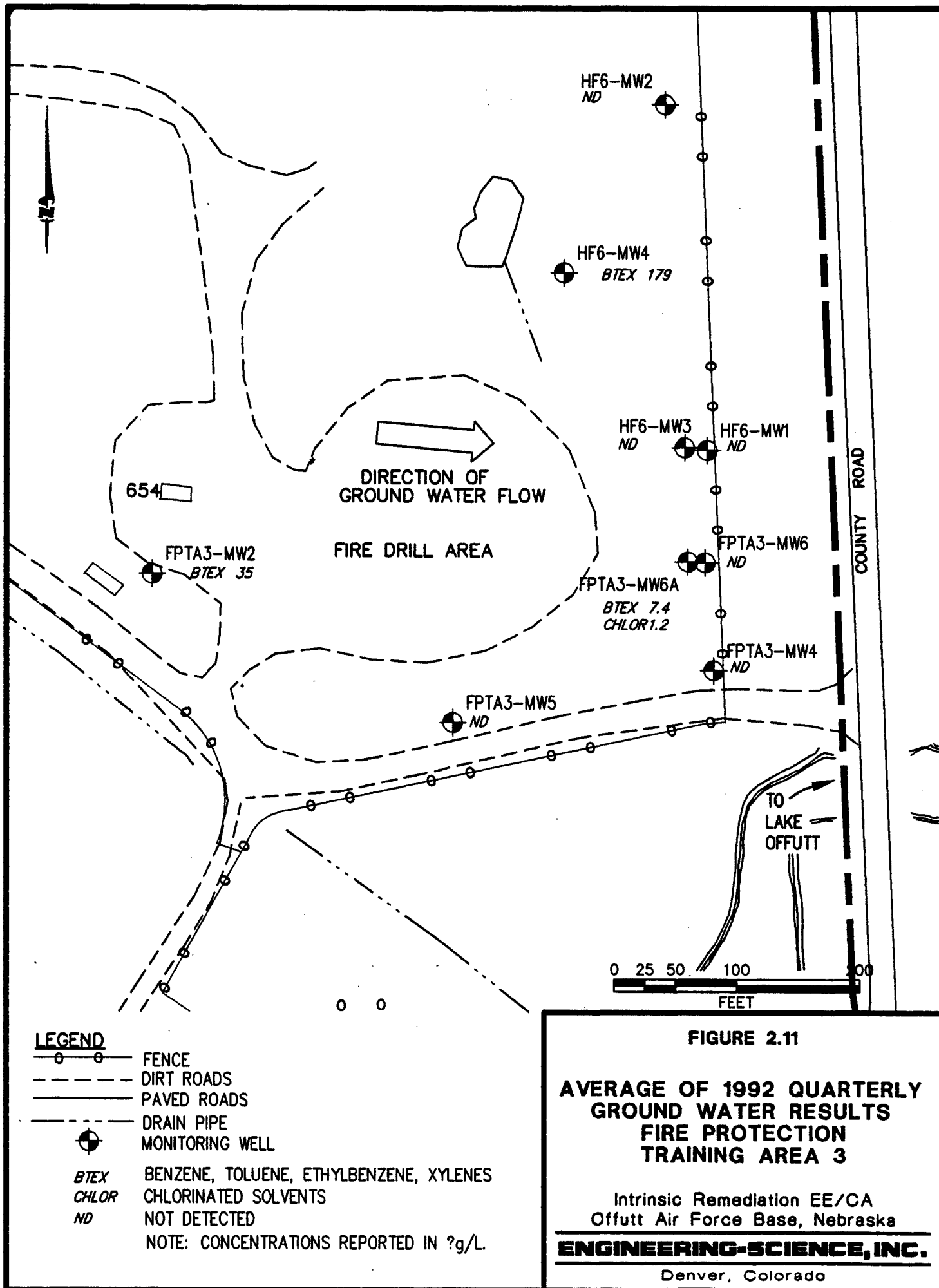


FIGURE 2.11

**AVERAGE OF 1992 QUARTERLY  
GROUND WATER RESULTS  
FIRE PROTECTION  
TRAINING AREA 3**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

**TABLE 2.7**  
**SUMMARY OF VOLATILE ORGANIC RESULTS IN GROUND WATER SAMPLES**  
**FIRE PROTECTION TRAINING AREA-3**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUTT AIR FORCE BASE, NEBRASKA

Analyte (ug/L) a/	FPTA3-MW1					FPTA3-MW2					FPTA3-MW3				
	10/27/88	8/10/89	3/20/92	5/26/92	8/21/92	11/3/88	8/10/89	3/19/92	5/26/92	8/20/92	10/27/88	8/10/89	3/20/92	5/26/92	8/20/92
Benzene	- b/	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-	-	1	82	-	-	-	-	-	-
Xylenes	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-
1,2-Dichloroethene (total)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Analyte (ug/L)	FPTA3-MW4					FPTA3-MW5					FPTA3-MW6				
	11/2/88	8/10/89	3/20/92	5/26/92	8/21/92	11/3/88	8/10/89	3/20/92	5/26/92	8/20/92	11/29/89	3/20/92	5/26/92	8/21/92	
Benzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Xylenes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1,2-Dichloroethene (total)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chloroform	-	-	-	-	-	-	-	-	-	-	1	-	-	-	
Methylene chloride	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Analyte (ug/L)	FPTA3-MW6A				HF6-MW2				HF6-MW4			
	3/20/92	5/26/92	8/21/92	9/19/91	3/19/92	5/21/92	8/20/92	9/19/91	3/19/92	5/21/92	8/20/92	9/19/91
Benzene	5.6	6.6	10	-	-	-	-	14	8.3	6.8	11	270
Ethylbenzene	-	-	-	-	-	-	-	77	44	34	200	49
Xylenes	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethene (total)	1.6	-	1.5	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	-	-	-	-	-	-	-	-	-	-	-	-

a/ Micrograms per Liter  
 b/ Not Detected

1991-92 average quarterly BTEX concentration was nearly 179 µg/L. Total BTEX concentrations at HF6-MW4 may be highest because the other downgradient wells are located farther from suspected sources. 1,2-DCE detected in ground water samples from FPTA3-MW6A, is the only chlorinated solvent which has been detected in site ground water samples. The maximum detected concentration was 1.6 µg/L in March 1992. Well FPTA3-MW6A is located over 400 feet downgradient from the potential chlorinated solvent source at Building 654. None of the site monitoring wells are located within the suspected source areas.

During September 1994, five CPT/LIF probes were pushed at FPTA-3. Three of these points were located within suspected source areas: two at the main burn pit and one at Building 654. At all three suspected source locations, the LIF identified residual- or free-phase hydrocarbon contamination. In addition, soil samples extracted at these locations were observed to be fuel saturated. For these reasons, ground water is expected to have high hydrocarbon concentrations near the main burn pit and Building 654; furthermore, free product is expected within both of the source areas. The extent of neither free-phase nor dissolved-phase plumes has been estimated due to the lack of monitoring wells in close proximity to suspected source areas. Contaminant concentrations detected in ground water samples from existing site monitoring wells have generally been either low or non-existent.

## 2.2 DEVELOPMENT OF CONCEPTUAL MODEL

A conceptual model is a three-dimensional representation of the hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose for developing a site conceptual model is to provide for an understanding of the mechanism for contaminant fate and transport and for identifying additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model provides a foundation for formulating decisions regarding additional data collection activities and potential remedial actions. The conceptual models for the Tank 349 Site and FPTA-3 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling hydrocarbon degradation using the Bioplume II model.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
  - Local geologic and topographic data,
  - Hydraulic data,
  - Site stratigraphic data,

- Contaminant concentration and distribution data;

- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors; and
- Determining additional data requirements.

## **2.2.1 Initial Conceptual Models**

### **2.2.1.1 Tank 349 Site**

Site hydrogeologic data were previously integrated to produce hydrogeologic cross sections of the site (Terracon, 1994). Cross section A - A' and B - B' (Figures 2.3 and 2.4) show the dominant hydrostratigraphic units present at the site and the water table elevation. Figure 2.5 is a ground water surface map prepared using March 1994 ground water elevation data (Terracon, 1994).

Ground water occurs in the clay-rich glacial till and interbedded fine sand stringers in the vicinity of Tank 349, and flows east toward the Missouri River. Based on available data, Parsons ES will model the site as an unconfined to semiconfined, clayey sand aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Free product is present at the Tank 349 Site; therefore, it may be necessary to use the fuel/water partitioning model of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the ground water. In order to use one of these models, samples of free product will be collected and analyzed for mass fraction of BTEX compounds.

### **2.2.1.2 FPTA-3**

Ground water occurs in alluvial deposits of the Missouri River flood plain, and flows east toward the Missouri River, as presented in Figure 2.7. Based on available data, Parsons ES will model the site as an unconfined clayey sand aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available. Hydrogeologic profiles will be developed as site information becomes available.

Free product is expected at two known source areas at FPTA-3: the main burn pit and Building 654. It may be necessary, therefore, to use the fuel/water partitioning model of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into

the ground water. In order to use a partitioning model, samples of free product will be collected (if encountered) and analyzed for mass fraction of BTEX compounds.

### **2.2.2 Potential Pathways and Receptors**

Potential preferential contaminant migration pathways such as ground water discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. The primary potential migration paths for contaminants at both sites are from remaining contaminated soils at the sites to the ground water and from the ground water to potential receptors via consumption or other use. Shallow ground water beneath the Base flows toward the Missouri River, or toward Papillion Creek which terminates 2 miles southeast of the Base at the Missouri River. It is unlikely that detectable concentrations of contaminants will reach either the Missouri River or Papillion Creek because of the processes of dilution, dispersion, and degradation. It is also unlikely that Offutt Lake, located east of FPTA-3, will be affected for the same reason. It is unlikely that free-phase product will enter surrounding buildings at either site because ground water at the Tank 349 site is approximately 40 feet bgs and the only building at FPTA-3 is abandoned. Ground water contamination is not known to have migrated beyond the boundaries of the Base from either the Tank 349 Site or FPTA-3.

The potential for exposure to contaminated water originating from either site through drinking water supplies is low because of the low permeability of the shallow ground water aquifers, a minimum distance of 2,000 feet to the nearest drinking water well from either site, and the classification of Offutt AFB as outside of well-head protection areas delineated for public water supplies (W-C, 1993; Terracon, 1994). The nearest public water supply wells are owned by and located in the City of Bellevue. The wells are at least 5,000 feet east (downgradient) of the Tank 349 site and 3,000 feet north (cross gradient) of FPTA-3 (B&V, 1990). The Base has purchased its water from the Municipal Utilities District (MUD) since 1976. The MUD well field is located approximately 4 miles southwest of the Base along the Platte River. Of the six former Base water supply wells, three have been abandoned and the other three are maintained for fire control. These wells are not connected to the Base water supply system nor are they pumped regularly (B&V, 1990).

A second potential migration pathway at FPTA-3 is directly from shallow contaminated soils within the main bermed burn area to potential receptors. As the site is secure and isolated in a low use area of the Base, flora and fauna are the probable receptors via consumption. Volatilization or adsorption to wind transported dust particles could potentially contribute to migration from the site. Because the areas of near surface contamination are enclosed by earthen berms, surface runoff is an unlikely migration pathway.

## SECTION 3

### COLLECTION OF ADDITIONAL DATA

To complete the EE/CA and to evaluate whether intrinsic remediation of fuel-related contaminants is occurring, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the EE/CA.

Physical hydrogeologic characteristics include:

- Depth from measurement datum to the ground water surface in existing monitoring wells;
- Locations of potential ground water recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimation of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Temperature; and
- Determination of extent and thickness of free- and residual-phase product.

Chemical hydrogeologic characteristics include:

- Dissolved oxygen (DO) concentration;
- Specific conductance;
- pH;
- Chemical analysis of free product to determine mass fraction of BTEX; and
- Additional chemical analysis of ground water and soil for the parameters listed in Table 3.1.

**TABLE 3.1**  
**ANALYTICAL PROTOCOL FOR**  
**GROUND WATER AND SOIL SAMPLES**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUTT AIR FORCE BASE, NEBRASKA

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
<b>WATER</b>		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe+2)	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe+3)	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfide	Colorimetric, HACH Method 8131	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	Direct reading meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Carbon Dioxide	Titrimetric, HACH Method 8223	F
Alkalinity (Carbonate [CO3-2] and Bicarbonate [HCO3-1])	Titrimetric, HACH Method 8221	F
Nitrate	E300 or SW9056	L
Nitrite	E300 or SW9056	L
Chloride	E300 or SW9056	L
Sulfate	E300 or SW9056	L
Alkalinity	E150.1	L
Methane	RSKSOP147	L
Total Organic Carbon	A5310C (RSKSOP-102)	L
Aromatic Hydrocarbons	SW8020 (RSKSOP-133)	L
Volatile Organics	SW8240 (RSKSOP-148)	L
Total Hydrocarbons	SW8015, modified	L
Free Product	GS/MSD fuel identification	L
<b>SOIL</b>		
Total Organic Carbon	SW9060	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	SW8020	L
Volatile Organics	SW8240	L
Total Hydrocarbons	SW8015, modified	L

Field work described in this work plan in support of the EE/CA is being completed in two phases. Phase I was completed in September 1994. The object of Phase I was to define the extent of residual- and free-phase hydrocarbon contamination using CPT testing in conjunction with LIF testing and limited soil sampling. Extensive CPT/LIF testing was performed at the Tank 349 site and a UST/fuel dispenser site located at Building 30; limited testing was performed at FPTA-3. As a result of Phase I testing, FPTA-3 was selected over the Building 30 site as the more promising site for an EE/CA in support of the intrinsic remediation option. The extent of residual- and free-phase hydrocarbon contamination was determined at the Tank 349 site; however, additional LIF testing will be required during Phase II at FPTA-3 to define the extent of residual- and free-phase hydrocarbons. Phase II activities will also include monitoring point installation, additional CPT testing, and ground water, free product, and soil sampling.

The following sections describe the procedures that were followed during Phase I and will be followed during Phase II when performing field investigations and collecting site-specific data. The CPT/LIF system is described in Section 3.1. Procedures for soil sample collection to verify CPT/LIF data are described in Section 3.1.2. Procedures for the installation of new monitoring points are described in Section 3.2. Procedures for sampling of existing ground water monitoring wells and newly installed ground water monitoring points are described in Section 3.3. Procedures for the measurement of aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.4.

### **3.1 CONE PENETROMETRY**

Subsurface conditions at the site will be characterized using CPT coupled with LIF. (This investigation was conducted in part in September 1994.) Cone penetrometry is an expeditious and effective means of analyzing the stratigraphy of a site by measuring the resistance against the conical probe of the penetrometer as it is pushed into the subsurface. Stratigraphy is determined from a correlation of the point stress at the probe tip and frictional stress on the side of the cone. Soil samples are collected to correlate the CPT readings to the lithologies present at the site.

CPT will be conducted using the US Army Corps of Engineers' (USACE's) cone penetrometer truck. This equipment consists of an instrumented probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is housed in a stainless steel, dual-compartment body mounted on a 43,000-pound, triple-axle Kenworth® truck chassis powered by a turbo-charged diesel engine. The weight of the truck and equipment is used as ballast to achieve the overall push capability of 39,000 pounds. This push capacity may be limited in tight soils by the structural bending capacity of the 1.40-inch outside-diameter (OD) push rods, rather than by the weight of the truck. The current 39,000-pound limitation is intended to minimize the possibility of push-rod buckling. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe is of standard dimensions, having a 1.40-inch OD, 60-degree conical point with sacrificial tip, and an 8.0-inch-long by 1.40-inch OD friction sleeve. Inside the probe, two load cells independently measure the vertical resistance against the



conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross-section which is instrumented with four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometry truck. A grout tube also runs down the push cylinder to allow the introduction of cement grout to the hole in order to seal the CPT hole. The USACE CPT is not equipped to monitor pore pressure; therefore, the location of the water table will not be measured using the CPT apparatus. Evaluation of point and sleeve stresses can often provide an estimated depth to ground water. The penetrometer is usually advanced vertically into the soil at a constant rate of 2 centimeters per second, although this rate must sometimes be reduced, such as when hard layers are encountered. Penetration, dissipation, and resistivity data will be used to determine potential site layering as it is encountered in the field.

The known propensity of aromatic hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology, in conjunction with CPT technology, to detect soil characteristics and hydrocarbon contamination simultaneously. The LIF is not capable of detecting chlorinated solvents. The LIF system has a 0.25-inch sapphire window in the side of the cone that allows a laser to scan the soil for fluorescent compounds as the LIF penetrometer rod pushes through soil. Assuming that aromatic hydrocarbons are simultaneously solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. Fiber optic cables connected to the laser spectrometer and a 6-pair electrical conductor connected to the CPT data acquisition system, are routed through the interior of the push tubes to the CPT probe.

The basic components of the LIF instrument are a nitrogen laser, a fiber optic probe, a monochromator for wavelength resolution of the return fluorescence, a photomultiplier tube to convert photons into an electrical signal, a digital oscilloscope for waveform capture, and a control computer. The fiber optic probe for the cone penetrometer consists of delivery and collection optical fibers, a protective sheath, a fiber optic mount within the cone, and a 0.25-inch sapphire window (Figure 3.1).

The results of each LIF/CPT push will be available 2 or 3 minutes after the completion of each hole. Graphs showing cone resistance, sleeve friction, soil classification, fluorescence intensity, and wavelength will be plotted by USACE personnel at the conclusion of each penetration and presented to the Parsons ES field scientist in order to allow investigative decisions to be based on the most current information.

### **3.1.1 CPT/LIF Testing Strategy**

The purpose of the LIF/CPT testing at the site is to determine subsurface stratigraphy and to better define the areal and vertical extent of residual fuel hydrocarbons in the unsaturated zone and free-phase hydrocarbons in the site ground water. The CPT will be pushed from ground surface to below fluorescing contamination, refusal, or up to 60 feet bgs, depending on contaminant distribution and subsurface conditions. In order to define the edges of the contaminant plume, testing results from 12 CPT/LIF points (completed September 1994) at Tank 349 Site and 15 CPT/LIF points (5 completed in

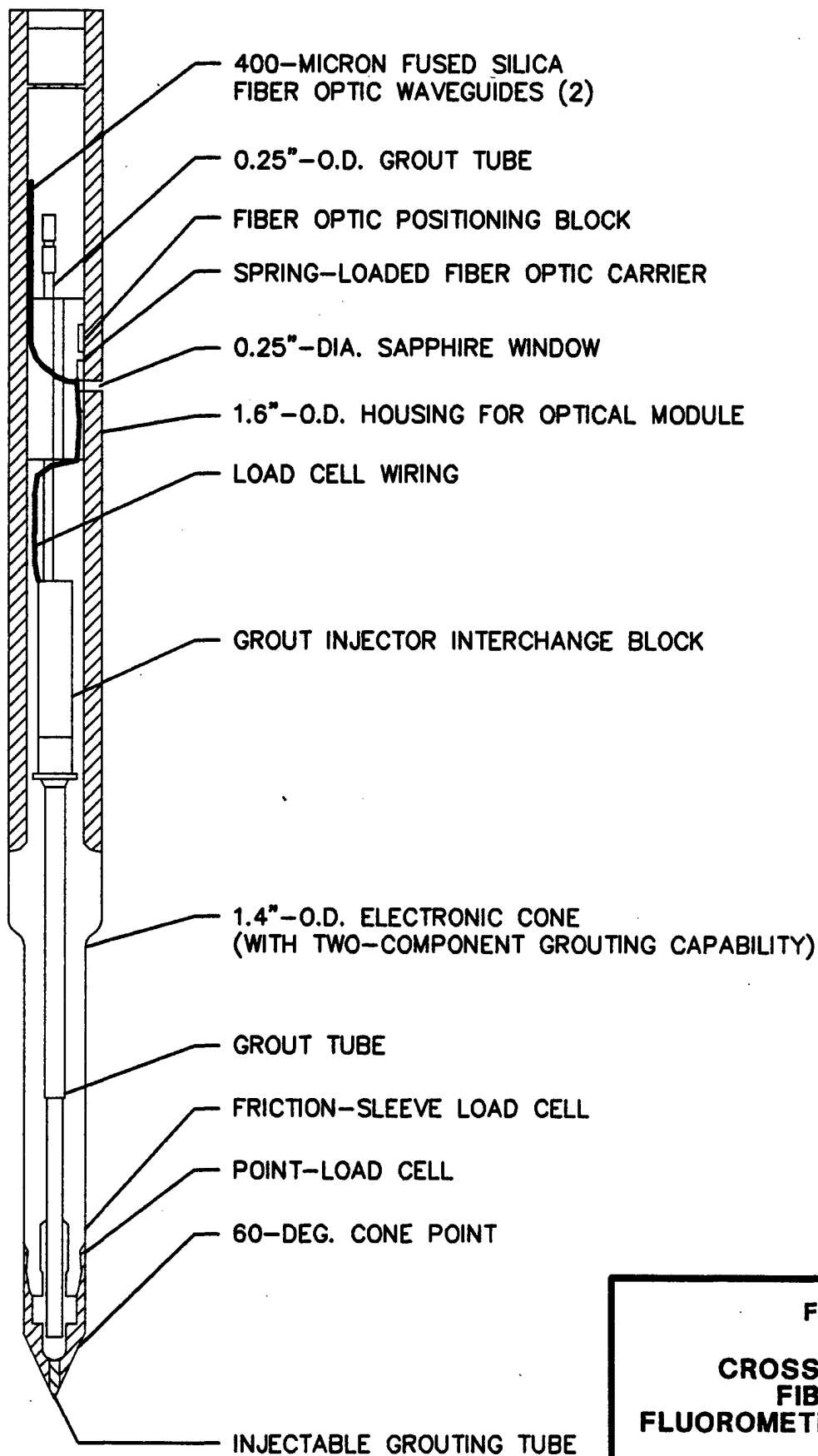


FIGURE 3.1.

**CROSS SECTION OF  
FIBER OPTIC  
FLUOROMETRY PENETROMETER**

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September 1994) at FPTA-3 are anticipated to be used. Figures 3.2 and 3.3 show the locations of the already completed (September 1994) and proposed CPT/LIF points at each site.

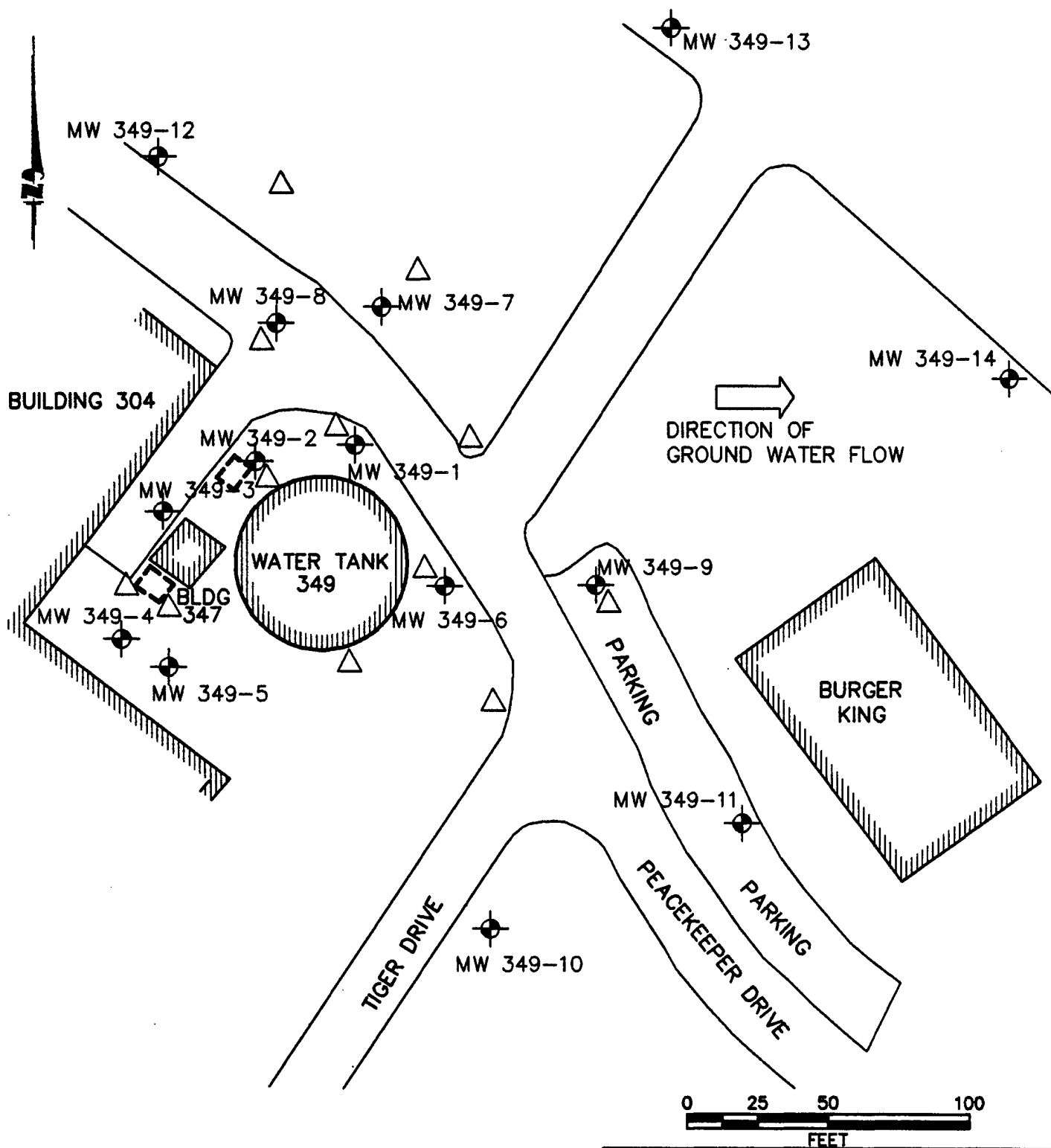
At the Tank 349 Site, CPT/LIF testing was performed September 23 through 27, 1994. LIF testing centered on the two former UST excavations using three points. The investigation proceeded downgradient (east) and laterally (north and south) until residual- and free-phase hydrocarbons were no longer detected with the LIF testing. The leading edge of residual- or free-phase hydrocarbons is south of MW 349-12, west of MW 349-13 and MW349-14, northwest of MW 349-9, and north of MW 349-10, MW 349-4, and MW 349-5. Figure 3.2 shows the locations of CPT/LIF data collection points at the Tank 349 Site. Results of this investigation will be reported in greater detail in the EE/CA report. No additional CPT/LIF points are proposed for this site.

At FPTA-3, CPT/LIF tests were performed at five locations during September 1994. An additional 10 LIF points are proposed for FPTA-3 in the upcoming investigations. At the conclusion of both investigations, at least one LIF test will have been performed at each of four potential source areas: the abandoned Building 654, the main bermed burn pit surrounding the model aircraft fuselage, the discharge pond, and the secondary bermed area. The investigation will define residual- or free-phase hydrocarbons downgradient (east) and laterally (north and south) of each source where the LIF detects hydrocarbons. The downgradient and lateral LIF investigations will cease when fluorescing hydrocarbons are no longer detected. At least one LIF test will be performed between each pair of sources with detected residual- or free-phase hydrocarbons to evaluate whether the sources form a contiguous plume. The free-phase plume edge is expected to nearly coincide with the berm surrounding the model aircraft fuselage. A second plume is expected to encompass the abandoned Building 654. It may merge with the first plume, but it is not believed to extend as far south as FPTA3-MW2. In addition to defining the downgradient extent of the plume, at least one location will be established west of the abandoned building to further define upgradient conditions. Figure 3.3 shows the proposed and completed locations for LIF data collection at FPTA-3.

Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any CPT activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed CPT/LIF locations indicated in Figures 3.2 and 3.3. AFCEE will be responsible for supplying a certified driller for the duration of the field work (if applicable).

### **3.1.2 Soil Sampling and Analysis**

To check the CPT soil classifications and calibrate the LIF data, soil samples from discrete intervals will be collected at the site. Soil samples will be collected from varied soil matrices (if present) from within the source area, at the fringe of the identified residual- or free-phase hydrocarbon plume, and outside of the plume. USACE CPT operators will collect soil samples using a Hoggen-Toggler<sup>®</sup> attachment for the CPT push rods.



- LEGEND**
- FORMER TANK EXCAVATION
  - MONITORING WELL
  - CPT/LIF SAMPLING LOCATIONS (SEPTEMBER 1994)

**FIGURE 3.2**

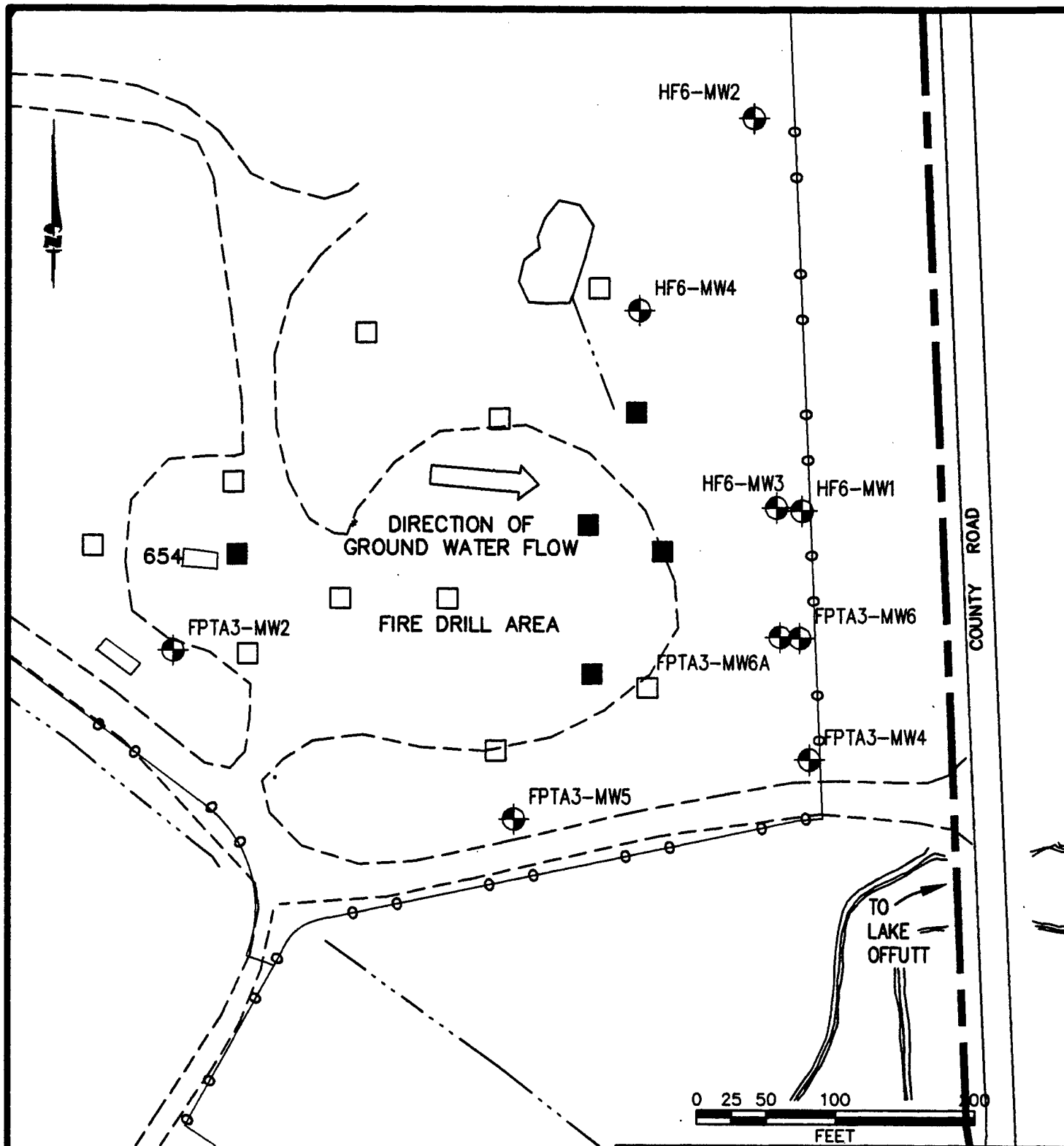
**CPT/LIF SAMPLING LOCATIONS  
TANK 349 SITE**

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# **LEGEND**

- FENCE
- DIRT ROADS
- DRAIN PIPE
- PAVED ROADS
- MONITORING WELL
- CPT/LIF SAMPLING LOCATION (SEPTEMBER 1994)
- CPT/LIF SAMPLING LOCATION (PROPOSED)

**FIGURE 3.3**

## **CPT/LIF SAMPLING LOCATIONS FIRE PROTECTION TRAINING AREA 3**

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A Hoggen Toggler® sampler generally can be used to collect undisturbed soil samples at any desired depth within the range of the driving apparatus. The sampler is coupled to the penetrometer rod and pushed into the soil with the CPT truck. With the Hoggen Toggler® cone in the closed position, soil is prevented from entering the sampling tube until the desired depth is achieved. When the sampler has been pushed to the depth at which the soil sample is to be taken, the sampling unit is raised a few inches and the Hoggen Toggler® apparatus is opened. The open Hoggen Toggler® is pushed to fill with soil, then pulled from the ground as quickly as possible. The Hoggen Toggler® sampling apparatus allows collection of 8-inch-long by 1-inch inside-diameter (ID) continuous samples. Recovery efficiencies for samples in saturated or sandy soils are often reduced, or the samples are compromised, because of spillage of the soil from the device after extraction. To mitigate this problem, soil samples will be compressed *in situ* with the penetrometer and Hoggen Toggler® assembly to expel the pore water before extraction.

If the Hoggen Toggler® sampling techniques described above are inappropriate, ineffective, or unable to efficiently provide sufficient soil volumes for the characterization of the site, continuous soil samples will be obtained from conventional soil boreholes using a split-spoon sampler, a hand auger, or another similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

Recovered soil will be placed in analyte-appropriate sample containers (Appendix A) and shipped to the analytical laboratory for analysis of BTEX, halogenated volatile organics (FPTA-3, only), total organic carbon (TOC), moisture content, and total petroleum hydrocarbons (TPH) by the analytical methods listed in Table 3.1. The lithology of recovered soil will be recorded for comparison and correlation with CPT results.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.4. The descriptive log will contain the following information:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and

# GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: \_\_\_\_\_ CONTRACTOR: \_\_\_\_\_ DATE SPUD: \_\_\_\_\_  
 CLIENT: AFCEE RIG TYPE: \_\_\_\_\_ DATE CMPL.: \_\_\_\_\_  
 JOB NO.: 722450.24 DRLG METHOD: \_\_\_\_\_ ELEVATION: \_\_\_\_\_  
 LOCATION: OFFUTT AFB BORING DIA.: \_\_\_\_\_ TEMP: \_\_\_\_\_  
 GEOLOGIST: \_\_\_\_\_ DRLG FLUID: \_\_\_\_\_ WEATHER: \_\_\_\_\_  
 COMENTS: \_\_\_\_\_

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res					TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)	Type	PID(ppm)	TLV(ppm)	BTEX(ppm)	TPH (ppm)		
	1												
	5												
	10												
	15												
	20												
	25												
	30												
	35												

## NOTES

bgs - Below Ground Surface  
 GS - Ground Surface  
 TOC - Top of Casing  
 NS - Not Sampled  
 SAA - Same As Above

## SAMPLE TYPE

D - DRIVE  
 C - CORE  
 G - GRAB

▼ Water level drilled

**FIGURE 3.4**

## GEOLOGIC BORING LOG

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- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

### **3.1.3 CPT Locations and Datum Survey**

The horizontal location of all CPT/LIF testing locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface will also be measured to the nearest 0.1 foot relative to US Geological Survey (USGS) MSL data. Sample location and other relevant site information for the soil cores collected for verification purposes will be recorded by the Parsons ES field scientist.

### **3.1.4 Site Restoration**

After sampling is complete, each CPT site will be restored as closely to its original condition as possible. Any test holes remaining open after extraction of the penetrometer rod will be sealed with hydrated bentonite chips, pellets, or grout to eliminate the creation or enhancement of contaminant migration pathways to the ground water.

### **3.1.5 Equipment Decontamination Procedures**

The CPT push rods will be cleaned with potable water using the USACE CPT steam-cleaning system (rod cleaner) as the rods are withdrawn from the ground. A vacuum system located beneath the CPT truck will be used to recover rinseate. Use of this system results in nearly 100-percent recovery of steam-cleaning rinseate from the rod cleaner. Rinseate is generated only as the rods move past the cleaner, thereby minimizing liquid waste generation. Care will be taken not to apply the pressurized steam to the LIF module which will be decontaminated by hand. Rinseate will be collected in 55-gallon drums. Filled 55-gallon drums will be stored at the Base, and Base personnel will arrange for final disposal of the drums and their contents. Base personnel are responsible for sampling the contents of the drums to identify any hazardous constituents before the drums are transported to an appropriate disposal facility.

Other downhole and sampling equipment will be decontaminated by steam cleaning or by the procedures specified in Section 3.3.2.1.

Potable water to be used in CPT equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact on the surrounding area that might result from decontamination operations.

## **3.2 PERMANENT MONITORING POINT INSTALLATION**

To further characterize the hydrogeologic conditions of the shallow subsurface, up to 22 additional monitoring points may be installed the Tank 349 site, and up to 28 additional monitoring points may be installed at FPTA-3. The following sections



describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures.

### 3.2.1 Monitoring Point Locations and Completion Intervals

The locations of 20 proposed monitoring points are identified for the Tank 349 site on Figure 3.5. Likewise, 27 proposed monitoring point locations are identified for FPTA-3 on Figure 3.6. The proposed locations for the new monitoring points were determined from a review of existing data gathered during previous site activities and preliminary EE/CA field investigations conducted in September 1994. Monitoring point locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. These proposed locations and quantities may be modified in the field as a result of encountered field conditions and acquired field data.

At the Tank 349 site, additional points are required to define the extent of the dissolved-phase plume both horizontally and vertically. Five monitoring point nests have been designated to help define the downgradient extent of the dissolved-phase hydrocarbon plume. Currently, there are no wells in the 100- to 200 foot-wide belt between MW 349-6 and MW 349-7 where free-phase hydrocarbons are present, and the downgradient wells MW 349-10, MW 349-13, and MW 349-14 where total BTEX concentrations do not exceed 3 µg/L. Another 10 monitoring points will be placed next to existing wells to help define vertical gradients and vertical extent of contamination. Single monitoring points are planned to be installed next to six monitoring wells. The remaining four monitoring points will be used to evaluate vertical extent of contamination next to monitoring wells MW 349-2 and MW 349-6 which contain free-phase hydrocarbons in the uppermost sandy zone; two monitoring points will be clustered with each monitoring well.

The necessity for additional monitoring points at FPTA-3 results from a lack of strategically placed monitoring points near probable source areas. Three-point monitoring nests will be placed at both the main burn pit and the abandoned building. Residual-phase hydrocarbons are known to be present at both of these locations, and free-phase product is suspected. An additional three two-point monitoring nests will be installed around the abandoned building to evaluate vertical and lateral extent of hydrocarbon and chlorinated solvent contamination. Two two-point nests will be installed to define contamination in the vicinity of the main burn pit, and an additional point will be installed next to FPTA3-MW5 for the same reason. A single point will be installed next to well HF6-MW4 to evaluate the vertical extent of contamination downgradient of the discharge pond. Four two-point nests will also be installed at FPTA-3 to investigate the leading edge of the dissolved-phase plume. A single monitoring point will be installed west of the abandoned Building 654 to evaluate background conditions.

Monitoring point nests will consist of two to three monitoring points: a shallow point intended to sample the shallow portion of the aquifer at or near the water table, and one or two deep points intended to sample the ground water lower in the aquifer.

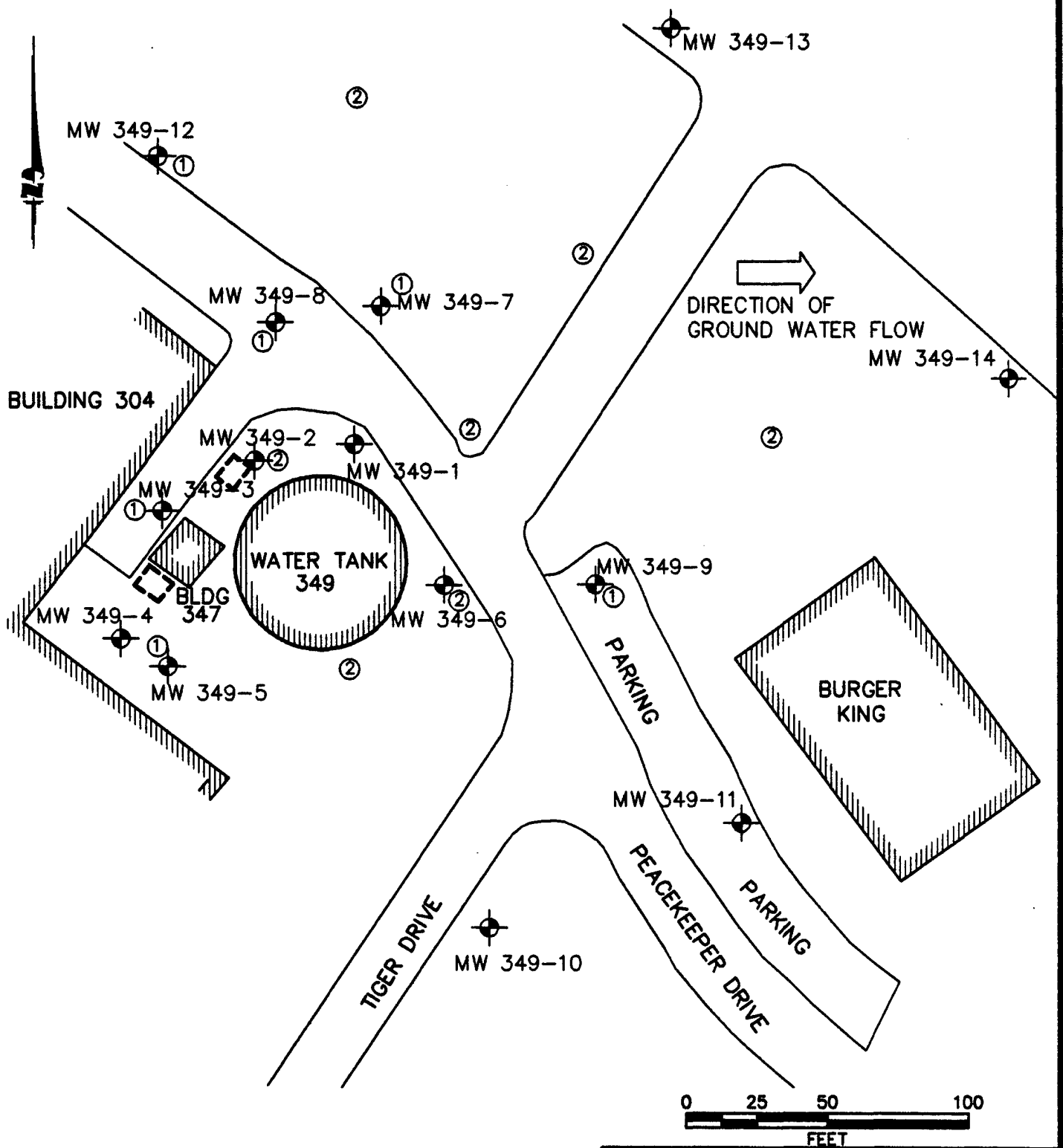


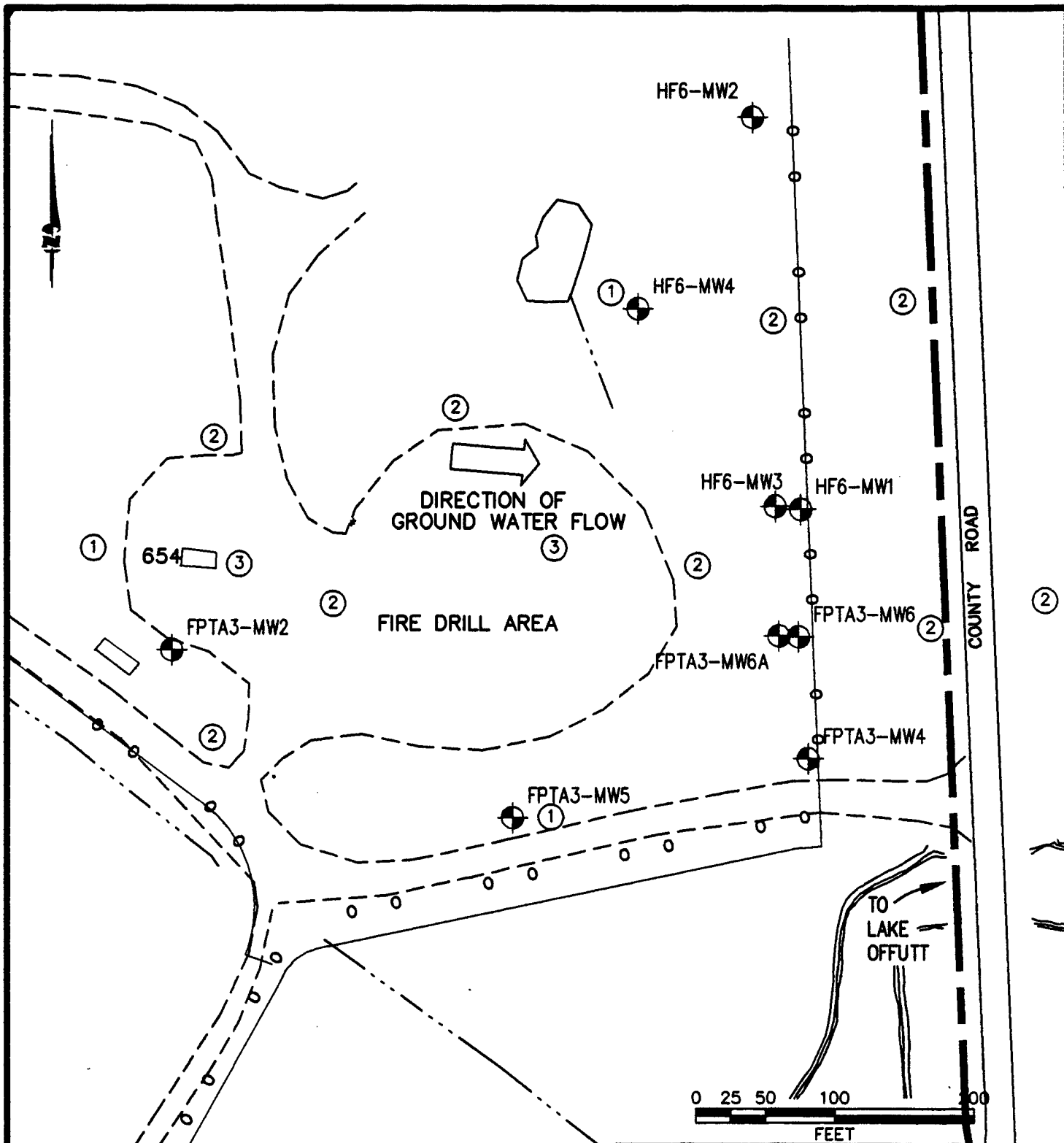
FIGURE 3.5

**PROPOSED  
MONITORING POINT LOCATIONS  
TANK 349 SITE**

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# **LEGEND**

- FENCE
- - - DIRT ROADS
- - - DRAIN PIPE
- PAVED ROADS
- ⊕ MONITORING WELL
- ② PROPOSED MONITORING POINT LOCATION AND NUMBER OF PROPOSED POINTS

## **FIGURE 3.8** **PROPOSED** **MONITORING POINT LOCATIONS** **FIRE PROTECTION** **TRAINING AREA 3**

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The shallow screened intervals will extend from 1 foot above the water table to 2 feet below the water table (or the uppermost saturated sandy zone at the Tank 349 Site). The deep points will be placed based on contaminant distribution and lithology. All monitoring points will be installed with 1 meter of screen. The proposed screened intervals of 1 meter will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated ground water in the monitoring point casing, and will give important information on the nature of hydraulic gradients in the area. Adjustments to the depth and length of the screened interval of the monitoring points may be necessary in response to actual aquifer conditions and contaminant stratification identified during LIF/CPT testing.

### **3.2.2 Monitoring Point Installation Procedures**

This section describes the procedures to be used for installation of new ground water monitoring points. All new monitoring points will be constructed of 0.75-inch OD/0.5-inch ID polyvinyl chloride (PVC) casing placed with a CPT pushrod using equipment described in Section 3.1.

#### **3.2.2.1 Pre-Placement Activities**

All necessary digging, drilling, and ground water monitoring point installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

#### **3.2.2.2 Ground Water Monitoring Point Installation**

##### ***3.2.2.2.1 Monitoring Point Materials Decontamination***

Monitoring point completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

##### ***3.2.2.2.2 Monitoring Point Screen and Casing***

At FPTA-3, ground water monitoring points will be installed by attaching 0.75-inch OD/0.5-inch ID PVC screen to a sacrificial tip and threading the monitoring point through the penetrometer pushrod. As the pushrod is pressed into the ground, new 0.75-inch OD/0.5-inch ID PVC casing will be continuously attached until the desired depth is reached and a fully cased monitoring point is created. Data collection devices

such as CPT and LIF will not be used during monitoring point placement; however, a CPT test will be performed at each monitoring point location prior to monitoring point placement in order to select desired depths.

As a result of the greater than 40-foot depth to ground water at the Tank 349 Site, installation of 0.5-inch ID monitoring points is undesirable due to the difficulty in developing, purging, and sampling narrow-diameter, monitoring points greater than 25 to 30 feet in depth. Instead, USACE staff will attempt to install monitoring points by attaching 1.9-inch OD/1.5-inch ID PVC screen to a 2.25-inch sacrificial tip and threading the penetrometer pushrod through the monitoring point. As the pushrod is pressed into the ground, new 1.9-inch OD/1.5-inch ID PVC casing will be continuously attached on the outside of the pushrod until the desired depth is reached. This technique will create a fully-cased monitoring point; however, it is uncertain if the CPT truck will be able to provide sufficient force to push large-diameter monitoring points to the desired depth. If the technique is not feasible, small-diameter monitoring points will be installed, or grab samples will be collected using the USACE HydroPunch® sampler, as described in Section 3.3.3.2.1.

Monitoring point casing and screens will be constructed of flush-threaded, Schedule 40 PVC. The screens will be factory slotted with 0.01-inch openings. Casing joints will not be glued. The PVC top cap will be vented to maintain ambient atmospheric pressure if the monitoring well is completed above-grade

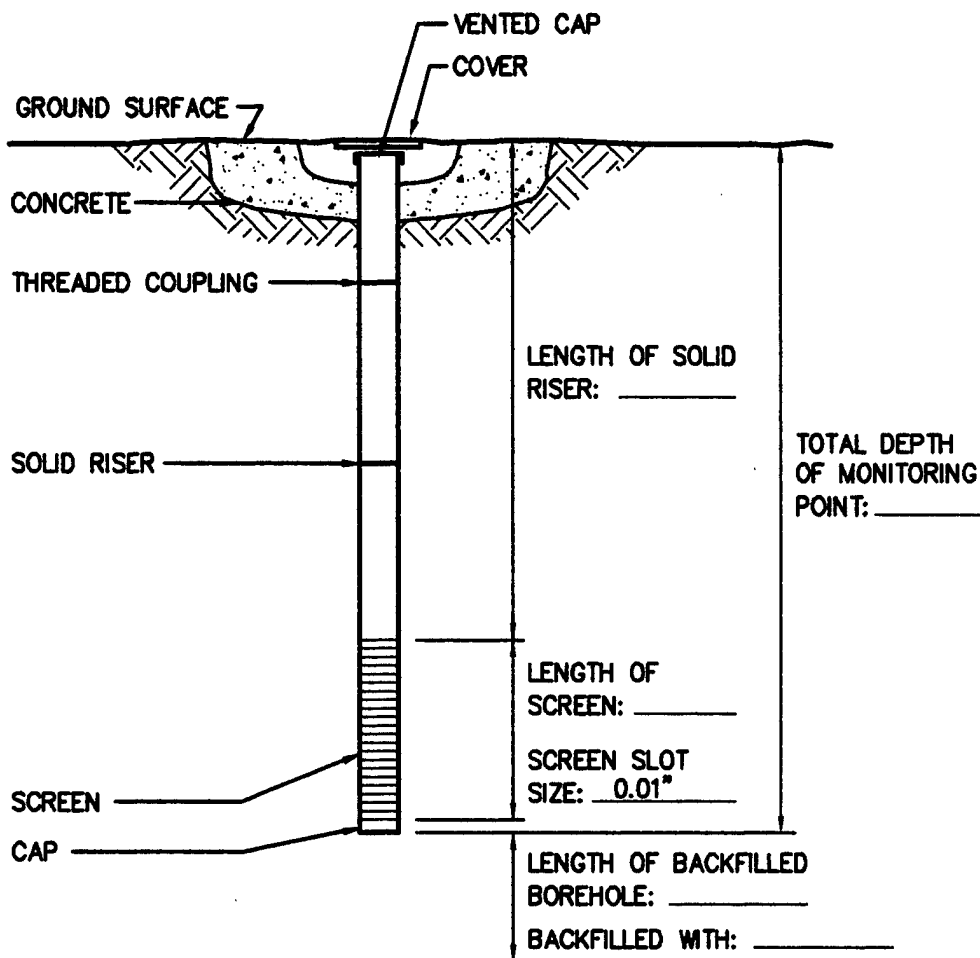
The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be recorded to the nearest 0.1 foot. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.7). This information will become part of the permanent field record for the site.

#### *3.2.2.2.3 Above-Grade and At-Grade Well Completion*

Each monitoring point will be completed with an at-grade protective cover or an above-grade protector pipe. Generally, at-grade completions will be used at the Tank 349 Site, and above-grade completions will be used at FPTA-3. In areas where pavement is present, the at-grade cover will be cemented in place using concrete blended to the existing pavement; otherwise, a concrete pad will be installed around the monitoring point. The concrete immediately surrounding the monitoring point will be sloped gently away from the protective casing to facilitate runoff during precipitation events. For above-grade completions, a steel protector pipe will be installed around the well point riser in order to protect the riser from damage. Each pipe will be painted a color designated by Base personnel and cemented into a 1-foot-square pad to ensure the stability of the post.

# MONITORING POINT INSTALLATION RECORD

JOB NAME OFFUTT AIR FORCE BASE MONITORING POINT NUMBER \_\_\_\_\_  
 JOB NUMBER 722450.24 INSTALLATION DATE \_\_\_\_\_ LOCATION \_\_\_\_\_  
 DATUM ELEVATION \_\_\_\_\_ GROUND SURFACE ELEVATION \_\_\_\_\_  
 DATUM FOR WATER LEVEL MEASUREMENT \_\_\_\_\_  
 SCREEN DIAMETER & MATERIAL \_\_\_\_\_ SLOT SIZE \_\_\_\_\_  
 RISER DIAMETER & MATERIAL \_\_\_\_\_ BOREHOLE DIAMETER \_\_\_\_\_  
 CONE PENETROMETER CONTRACTOR \_\_\_\_\_ ES REPRESENTATIVE \_\_\_\_\_



(NOT TO SCALE)

**FIGURE 3.7**

## MONITORING POINT INSTALLATION RECORD

STABILIZED WATER LEVEL \_\_\_\_\_ FEET  
 BELOW DATUM.  
 TOTAL MONITORING POINT DEPTH \_\_\_\_\_ FEET  
 BELOW DATUM.  
 GROUND SURFACE \_\_\_\_\_ FEET

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#### **3.2.2.4 Monitoring Point Development**

The new monitoring points will be developed prior to sampling. Development removes sediment from inside the monitoring point casing and flushes fines from the portion of the formation adjacent to the monitoring point screen.

Monitoring point development will be accomplished using a peristaltic pump with dedicated tubing provided by Parsons ES. The pump tubing will be regularly lowered to the bottom of the monitoring point so that fines which have accumulated in the bottom are agitated and removed from the monitoring point.

Development will be continued until a minimum 10 casing volumes of water has been removed from the monitoring point and until pH, temperature, specific conductivity, DO, and water clarity (turbidity) stabilize. If the water remains turbid, monitoring point development will continue until the turbidity of the water produced has been stable after the removal of several casing volumes.

A monitoring point development record will be maintained for each point. The monitoring point development record will be completed in the field by the field scientist. Figure 3.8 is an example of the monitoring point development record. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Predevelopment water level and monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Postdevelopment water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

Development waters will be collected in 55-gallon drums. Filled 55-gallon drums will be placed on pallets and transported by Base personnel to the Base's designated hazardous waste collection area.

#### **3.2.2.5 Water Level Measurements**

Water levels at existing monitoring wells and newly installed monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe.

# MONITORING POINT DEVELOPMENT RECORD

Page\_\_ of\_\_

Job Number: \_\_\_\_\_  
Location \_\_\_\_\_  
Well Number \_\_\_\_\_

Job Name: \_\_\_\_\_  
By \_\_\_\_\_ Date \_\_\_\_\_  
Measurement Datum \_\_\_\_\_

## Pre-Development Information

Time (Start): \_\_\_\_\_

Water Level: \_\_\_\_\_

Total Depth of Well: \_\_\_\_\_

### Water Characteristics

Color \_\_\_\_\_ Clear Cloudy  
Odor: None Weak Moderate Strong  
Any Films or Immiscible Material \_\_\_\_\_  
pH \_\_\_\_\_ Temperature (°F °C) \_\_\_\_\_  
Specific Conductance (µS/cm) \_\_\_\_\_

## Interim Water Characteristics

Gallons Removed \_\_\_\_\_

pH \_\_\_\_\_

Temperature (°F °C) \_\_\_\_\_

Specific Conductance (µS/cm) \_\_\_\_\_

## Post-Development Information

Time (Finish): \_\_\_\_\_

Water Level: \_\_\_\_\_

Total Depth of Well: \_\_\_\_\_

Approximate Volume Removed: \_\_\_\_\_

### Water Characteristics

Color \_\_\_\_\_ Clear Cloudy  
Odor: None Weak Moderate Strong  
Any Films or Immiscible Material \_\_\_\_\_  
pH \_\_\_\_\_ Temperature (°F °C) \_\_\_\_\_  
Specific Conductance (µS/cm) \_\_\_\_\_

Comments: \_\_\_\_\_

**FIGURE 3.8**

## **MONITORING POINT DEVELOPMENT RECORD**

Intrinsic Remediation EE/CA  
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### **3.2.2.6 Monitoring Point Location and Datum Survey**

The location and elevation of the new monitoring points will be surveyed soon after point completion. The horizontal location will be measured relative to established Base coordinates. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface adjacent to the monitoring point casing and the measurement datum elevation (top of PVC casing) will be measured relative to the USGS MSL datum. The ground surface elevation will be measured to the nearest 0.1 foot and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

### **3.2.3 Site Restoration**

After monitoring point installation and sampling is complete, each site will be restored as closely as possible to its original condition. Clean and contaminated development waters and sampling purge waters will be stored in 55-gallon drums and transported by Base personnel to the designated area used for collection of hazardous wastes at the Base.

## **3.3 GROUND WATER SAMPLING**

This section describes the scope of work required for collection of ground water quality samples at existing ground water monitoring wells, newly installed monitoring points, and at holes punched with modified cone penetrometer equipment. A peristaltic pump with Teflon®-lined, polyethylene tubing will be used to collect ground water samples at FPTA-3. At the Tank 349 site, a peristaltic pump can not be used due to the depth to ground water; therefore, a Grundfos Redi-Flo 2® submersible pump will be used to sample the existing 2-inch wells. If 1.5-inch ID monitoring points are successfully installed, a Waterra® inertial pump or small diameter Grundfos Redi-Flo 2® pump (if available) will be used for sample collection. If 0.5-inch ID monitoring points or HydroPunch® locations are required at the Tank 349 site, bailers will be used to collect ground water samples. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parson ES and the EPA/Robert S. Kerr Research Laboratory (EPA/RSKERL) who are trained in the conduct of ground water sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. The following activities will occur during ground water sampling:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
  - Protective cover, cap, and lock,
  - External surface seal and pad,

- Monitoring point stick-up, cap, and datum reference, and
- Internal surface seal;
- Ground water sampling, including
  - Water level and product thickness measurements,
  - Visual inspection of sample water,
  - Monitoring point casing evacuation, and
  - Sample collection;
- Sample preservation and shipment, including
  - Sample preparation,
  - Onsite measurement of physical parameters, and
  - Sample labeling;
- Completion of sampling records: and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

### **3.3.1 Ground Water Sampling Strategy**

Ground water samples will be collected from existing monitoring wells and newly installed ground water monitoring points at both sites. Ground water samples may also be collected at several locations using a modified CPT/HydroPunch® procedure that allows discrete ground water samples to be collected.

#### **3.3.1.1 Monitoring Well and Monitoring Point Sampling Locations**

Existing ground water monitoring wells at the Tank 349 site and FPTA-3 will be sampled (e.g., wells MW 349-1 through MW 349-14, FPTA3-MW1 through FPTA3-MW6A, HF6-MW2, and HF6-MW4). All newly installed monitoring points will also be sampled (Section 3.2.1).

#### **3.3.1.2 Modified CPT Ground Water Sampling Locations**

Ground water samples may be collected using modified CPT equipment (e.g. HydroPunch®) at some or all of the proposed monitoring point locations shown in Figures 3.5 and 3.6. The number of locations sampled using the modified CPT equipment is dependent on the success of installing monitoring points with the USACE CPT. The methods to be used to sample ground water at these locations are described in

Section 3.3.3. It may be necessary to collect all proposed monitoring point ground water samples using this method if permanent monitoring point installation is not possible.

### **3.3.2 Preparation for Sampling**

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

#### **3.3.2.1 Equipment Cleaning**

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the CPT soil sampling tool, water level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropanol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the Ground Water Sampling Record (Figure 3.9).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the EPA mobile laboratory's permanent record of the sampling event.

#### **3.3.2.2 Equipment Calibration**

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of DO, carbon dioxide, pH, electrical conductivity, temperature, reduction/oxidation potential, sulfate, nitrate, and ferrous iron ( $\text{Fe}^{2+}$ ).

SAMPLING LOCATION \_\_\_\_\_  
SAMPLING DATE(S) \_\_\_\_\_

GROUND WATER SAMPLING RECORD - MONITORING WELL \_\_\_\_\_  
(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;  
DATE AND TIME OF SAMPLING: \_\_\_\_\_, 19\_\_\_\_ a.m./p.m.

SAMPLE COLLECTED BY: \_\_\_\_\_ of \_\_\_\_\_

WEATHER: \_\_\_\_\_

DATUM FOR WATER DEPTH MEASUREMENT (Describe): \_\_\_\_\_

MONITORING WELL CONDITION:

☐ LOCKED: \_\_\_\_\_ ☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: \_\_\_\_\_

INNER PVC CASING CONDITION IS: \_\_\_\_\_

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): \_\_\_\_\_

Check-off

1 ☐ EQUIPMENT CLEANED BEFORE USE WITH \_\_\_\_\_  
Items Cleaned (List): \_\_\_\_\_

2 ☐ PRODUCT DEPTH \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_

WATER DEPTH \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):  
Appearance: \_\_\_\_\_  
Odor: \_\_\_\_\_  
Other Comments: \_\_\_\_\_

4 ☐ WELL EVACUATION:  
Method: \_\_\_\_\_  
Volume Removed: \_\_\_\_\_  
Observations: Water (slightly - very) cloudy  
Water level (rose - fell - no change)  
Water odors: \_\_\_\_\_  
Other comments: \_\_\_\_\_

FIGURE 3.9

**GROUND WATER  
SAMPLING RECORD**

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5 [ ] **SAMPLE EXTRACTION METHOD:**

- [ ] Bailer made of: \_\_\_\_\_  
[ ] Pump, type: \_\_\_\_\_  
[ ] Other, describe: \_\_\_\_\_

Sample obtained is ☐ GRAB; ☐ COMPOSITE SAMPLE

## 6 [ ] ON-SITE MEASUREMENTS:

Temp: \_\_\_\_\_ ° \_\_\_\_\_ Measured with: \_\_\_\_\_  
pH: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Conductivity: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Dissolved Oxygen: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Redox Potential: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Salinity: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Nitrate: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Sulfate: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Ferrous Iron: \_\_\_\_\_ Measured with: \_\_\_\_\_  
Other: \_\_\_\_\_

7 [ ] SAMPLE CONTAINERS (material, number, size): \_\_\_\_\_

## 8 [ ] ON-SITE SAMPLE TREATMENT:

- [ ] Filtration: Method \_\_\_\_\_ Containers: \_\_\_\_\_  
Method \_\_\_\_\_ Containers: \_\_\_\_\_  
Method \_\_\_\_\_ Containers: \_\_\_\_\_

- [ ] Preservatives added:
- |              |                   |
|--------------|-------------------|
| Method _____ | Containers: _____ |
| Method _____ | Containers: _____ |
| Method _____ | Containers: _____ |
| Method _____ | Containers: _____ |

9 [ ] CONTAINER HANDLING:

- ☐ Container Sides Labeled
- ☐ Container Lids Taped
- ☐ Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS: \_\_\_\_\_

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**FIGURE 3.9 (CONTINUED)**

# GROUND WATER SAMPLING RECORD

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### **3.3.3 Sampling Procedures**

Special care will be taken to prevent contamination of the ground water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and through cross-contamination due to insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.2.1. Dedicated tubing will be used at each well or monitoring point developed, purged, and/or sampled with the peristaltic pump. The Grundfos Redi-Flo 2® submersible pump, the Waterra® inertial pump, and nondisposable bailers will be decontaminated according to procedures listed in Section 3.3.2.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different well or monitoring point is sampled. Dedicated, disposable bailers may be used on the 2-inch ID existing wells. The following paragraphs present the procedures to be followed for ground water sample collection from ground water monitoring wells and monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

#### **3.3.3.1 Ground Water Monitoring Well and Monitoring Point Sampling**

##### ***3.3.3.1.1 Preparation of Location***

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point.

##### ***3.3.3.1.2 Water Level and Total Depth Measurements***

Prior to removing any water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well/point and the depth will be measured to the nearest 0.01 foot. If free-phase product is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe and cord. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If free-phase product is encountered, the thickness of the product will be measured with an oil/water interface probe.

##### ***3.3.3.1.3 Monitoring Well/Point Purging***

The volume of water contained within the monitoring well/point casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well/point. All purge water will be placed in 55-gallon drums and disposed of by

Base personnel in the Base's approved disposal location as directed by authorized Base personnel. Emptied 55-gallon drums will be handled by Base personnel. A Grundfos Redi-Flo 2® submersible pump will be used for monitoring well purging, a peristaltic pump will be used for monitoring point purging, depth permitting, and either a Waterra® inertial pump or bailer will be used to purge all monitoring points in which the other two pumps will not work.

If a monitoring well/point is evacuated to a dry state during purging, the monitoring well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well/point to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

#### *3.3.3.1.4 Sample Extraction*

Dedicated, Teflon®-lined, HDPE tubing and a peristaltic pump will be used to extract ground water samples from monitoring wells/points whenever depth to ground water permits; otherwise, a Waterra® inertial pump, Grundfos Redi-Flo 2® pump, or bailer will be used. The tubing, pump, or bailer will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the EPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for monitoring well/point purge waters and transported for disposal by Base personnel to the facilities provided by the Base.

#### *3.3.3.2 Modified CPT Sampling*

##### *3.3.3.2.1 Preparation of Location*

Prior to starting the sampling procedure, the area around the penetrometer insertion point will be cleared of foreign materials, such as brush, rocks, or debris. This will prevent sampling equipment from inadvertently contacting foreign materials near the sampling point.

##### *3.3.3.2.2 Sampling Interval and Method*

The sampling depth and interval will be specified prior to driving the CPT pushrod into the ground. A disposable drive tip fitted with a Teflon® screen fitted with a nylon fabric mesh will be placed on the tip of the pushrod, and the rod will be pushed into the ground using the same truck, frames, and hydraulic equipment described in Section 3.1. After reaching the desired depth, the penetrometer pushrod will be raised 1 to 3 feet to allow decoupling of the disposable drive tip and to allow water to percolate into the end of the hollow pushrod. Water samples will be collected from water entering the

downhole, open end of the pushrod through the Teflon<sup>®</sup> screen with a 0.75-inch Teflon<sup>®</sup> bailer or a peristaltic pump. The ground water sample will be acquired as described in Section 3.3.3.2.4.

#### **3.3.3.2.3 Water Level and Total Depth Measurements**

Prior to removing any water from the modified CPT sample location, the static water level will be measured. An electric water level probe will be inserted into the pushrod until it confirms that ground water has been reached.

#### **3.3.3.2.4 Sample Extraction**

A 0.75-inch Teflon<sup>®</sup> bailer or peristaltic pump will be used to extract ground water samples from the modified CPT sampling locations. Prior to sample collection, ground water will be purged until DO and temperature readings have stabilized. The sample will be transferred directly to the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the EPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed in a 55-gallon drum and transported for disposal by Base personnel to the Base disposal facilities.

### **3.3.4 Onsite Ground Water Parameter Measurement**

As indicated on Table 3.1, many of the ground water chemical parameters will be measured onsite by EPA/RSKERL staff. Some of the measurements will be made with direct-reading meters, while others will be made using of a HACH<sup>®</sup> portable colorimeter in accordance with specific HACH<sup>®</sup> analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox<sup>®</sup> and water, and rinsing with deionized water and ethanol to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the ground water sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during ground water analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for later transfer by Base personnel to the approved disposal facility.

#### **3.3.4.1 Dissolved Oxygen Measurements**

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before and immediately following ground water sample acquisition. When DO measurements are taken in monitoring wells/points that have not



yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

#### **3.3.4.2 pH, Temperature, and Specific Conductance**

Because the pH, temperature, and specific conductance of a ground water sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the ground water sampling record (Figure 3.9).

#### **3.3.4.3 Carbon Dioxide Measurements**

Carbon dioxide concentrations in ground water will be measured in the field by experienced EPA/RSKERL scientists via titrimetric analysis using HACH® Method 8223 (0 to 250 mg/L as CO<sub>2</sub>). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.4.

#### **3.3.4.4 Alkalinity Measurements**

Alkalinity in ground water helps buffer the ground water system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the ground water sample will be measured in the field by experienced EPA/RSKERL scientists via titrimetric analysis using EPA-approved HACH® Method 8221 (0 to 5,000 mg/L as calcium carbonate).

#### **3.3.4.5 Nitrate- and Nitrite-Nitrogen Measurements**

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or ground water conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in ground water will be measured in the field by experienced EPA/RSKERL scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in ground water samples will be analyzed after preparation with HACH® Method 8039 (0 to 30.0 mg/L NO<sub>3</sub>). Nitrite concentrations in ground water samples will be analyzed after preparation with EPA-approved HACH® Method 8507 (0 to 0.35 mg/L NO<sub>2</sub>).

#### **3.3.4.6 Sulfate and Sulfide Sulfur Measurements**

Sulfate in ground water is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. An EPA/RSKERL scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate

sample preparation. EPA-approved HACH® Methods 8051 (0 to 70.0 mg/L SO<sub>4</sub>) and 8131 (0.60 mg/L S<sup>2-</sup>) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

#### **3.3.4.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements**

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the oxidation/reduction potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 for total soluble iron (0 to 3.0 mg/L Fe<sup>3+</sup> + Fe<sup>2+</sup>) and HACH® Method 8146 for ferrous iron (0 to 3.0 mg/L Fe<sup>2+</sup>) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

#### **3.3.4.8 Manganese Measurements**

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. EPA approved HACH® Method 8034 (0 to 20.0 mg/L) will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.4.

#### **3.3.4.8 Redox Potential**

The reduction/oxidation (redox) potential of ground water is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in ground water are usually biologically mediated; therefore, the redox potential of a ground water system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a ground water sample taken inside the contaminant plume should be somewhat less than that taken in the upgradient location.

The redox potential of a ground water sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis.

### **3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS**

This section describes the handling of samples from the time of sampling until the samples are delivered to EPA mobile laboratory.

### **3.4.1 Sample Preservation**

The EPA laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C). Samples will be delivered promptly to EPA mobile laboratory personnel, who will be responsible for shipment of appropriate samples to the RSKERL in Ada, Oklahoma for analysis.

### **3.4.2 Sample Container and Labels**

Sample containers and appropriate container lids will be provided by the EPA mobile laboratory (see Appendix A). The sample containers will be filled as described in Section 3.3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., ground water, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

### **3.4.3 Sample Shipment**

After the samples are sealed and labeled, they will be packaged for transport to the onsite EPA mobile laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the EPA mobile laboratory. Delivery will occur as soon as possible after sample acquisition.

#### **3.4.4 Chain-of-Custody Control**

Chain-of-custody documentation for the shipment of samples from the EPA mobile laboratory to the EPA/RSKERL analytical laboratory in Ada, Oklahoma, will be the responsibility of the EPA/RSKERL field personnel.

#### **3.4.5 Sampling Records**

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance, and
  - Sample odor;
- Weather conditions;
- Water level prior to purging (ground water samples, only);
- Total monitoring well/point depth (ground water samples, only);
- Sample depth (soil samples, only);
- Purge volume (ground water samples, only);
- Water level after purging (ground water samples, only);
- Monitoring well/point condition (ground water samples, only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (ground water samples, only); and
- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure 3.9 shows an example of the ground water sampling record. Soil sampling information will be recorded in the field log book.

### 3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all ground water and soil samples as well as the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, EPA/RSKERL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with EPA protocol or those reported in Appendix A of this plan.

EPA/RSKERL laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers, ice chests with adequate padding, and cooling media may be provided by EPA/RSKERL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the mobile laboratory.

## 3.5 AQUIFER TESTING

Slug tests will be conducted on selected existing wells (at least 3 per site) to estimate the hydraulic conductivity of unconsolidated sand, silt, and clay deposits at the two sites. This information is required to accurately estimate the velocity of ground water and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft<sup>2</sup>/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

### 3.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the

water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.

- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

### 3.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon®, PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger®, In-Situ, Inc. Model SE1000B, or equivalent).

### 3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.2.1.

### 3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following paragraphs describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the Aquifer Slug Test Data Form (Figure 3.10) with entries for:
  - Borehole/well number,
  - Project number,
  - Project name,
  - Aquifer testing team,
  - Climatic data,
  - Ground surface elevation,
  - Top of well casing elevation,
  - Identification of measuring equipment being used,
  - Page number,
  - Static water level, and
  - Date.
4. Measure the static water level in the well to the nearest 0.01 foot.
5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
6. Lower the decontaminated slug into the well to just above the water level in the well.
7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.

# Aquifer Slug Test Data Sheet

Location _____	Client _____	Well No. _____
Job No. _____	Field Scientist _____	Date _____
Water Level _____	Total Well _____	
Depth _____		
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]

**FIGURE 3.10**

# AQUIFER TEST DATA FORM

**Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska**

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Denver, Colorado



8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial slug.

#### **3.5.5 Rising Head Test**

After completion of the falling head test, the rising head test will be performed. The following paragraphs describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial slug.

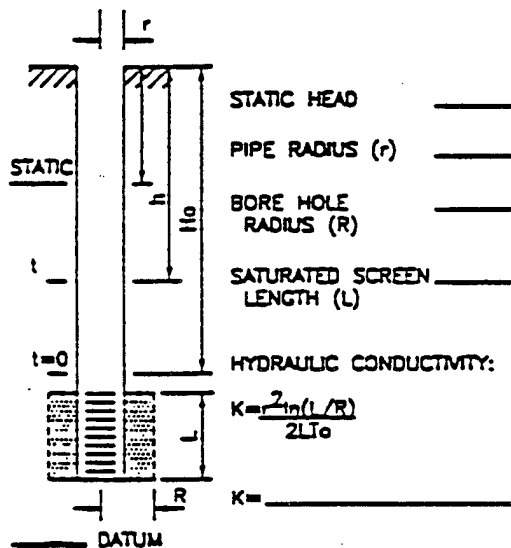
#### **3.5.6 Slug Test Data Analysis**

Data obtained during slug testing will be analyzed using AQTESOLV™ and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The standard slug test form (Figure 3.11) is based on equations and test methods developed by Hvorslev (1951). Figure 3.12 is the Bouwer and Rice Analysis Data Form. Figure 3.13 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice Analysis.

# HVORSLEV'S METHOD FOR K

PROJECT \_\_\_\_\_  
WELL NUMBER \_\_\_\_\_  
DATE \_\_\_\_\_

LOCATION \_\_\_\_\_  
ELEVATION \_\_\_\_\_



TIME (MIN)	WATER DEPTH (FT)	RECOVERY TO STATIC ± (WATER DEPTH-STAT)	$\frac{h}{H_0}$
STATIC			
00		(H <sub>0</sub> )	1.00
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	

K = \_\_\_\_\_ FT/MIN    K = \_\_\_\_\_ FT/DAY    K = \_\_\_\_\_ CM/SEC

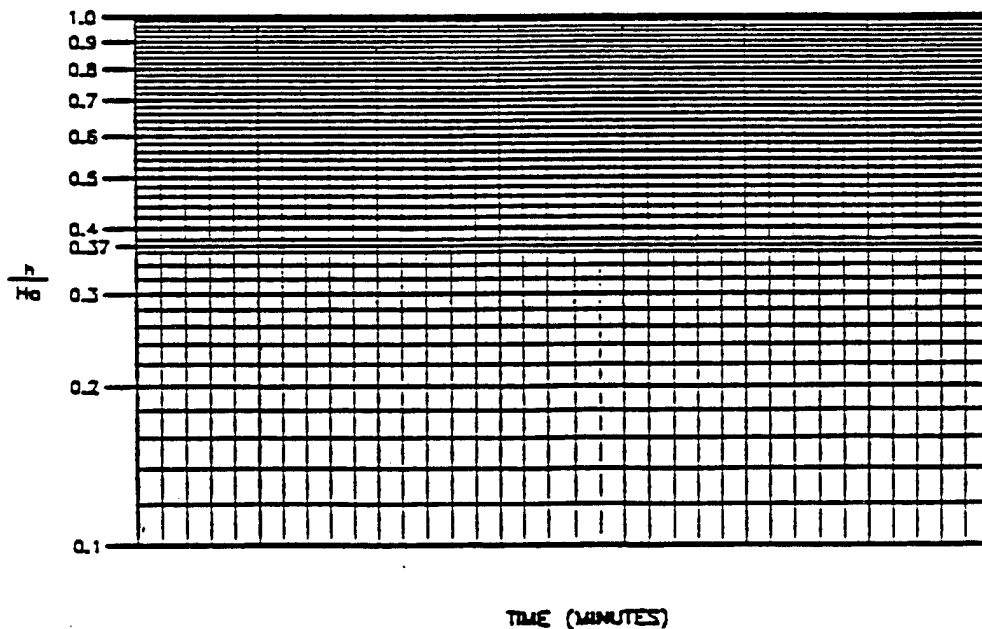


FIGURE 3.11

## SLUG TEST FORM

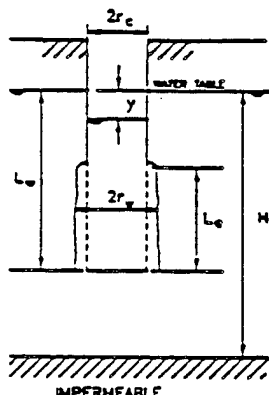
Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

(Reference: GROUNDWATER - May, June 1989, Vol. 27, No. 3)

PROJECT \_\_\_\_\_ LOCATION \_\_\_\_\_  
WELL NUMBER \_\_\_\_\_ ELEVATION \_\_\_\_\_  
DATE \_\_\_\_\_



STATIC HEAD \_\_\_\_\_

PIPE RADIUS ( $r_c$ ) \_\_\_\_\_

BORE HOLE  
RADIUS ( $r_w$ ) \_\_\_\_\_

SATURATED SCREEN \_\_\_\_\_  
LENGTH ( $L_s$ )

WELL DEPTH \_\_\_\_\_

HYDRAULIC CONDUCTIVITY:  
(ASSUME  $L_v = H$ )

$$K = \frac{(r_c) \ln(R_c/r_w)}{2Lq} \quad \begin{bmatrix} 1 \\ t \end{bmatrix} \ln \begin{bmatrix} y_0 \\ y_1 \end{bmatrix}$$

Ken \_\_\_\_\_

K=\_\_\_\_\_ FT/MIN    K=\_\_\_\_\_ FT/DAY    K=\_\_\_\_\_ CM/SEC

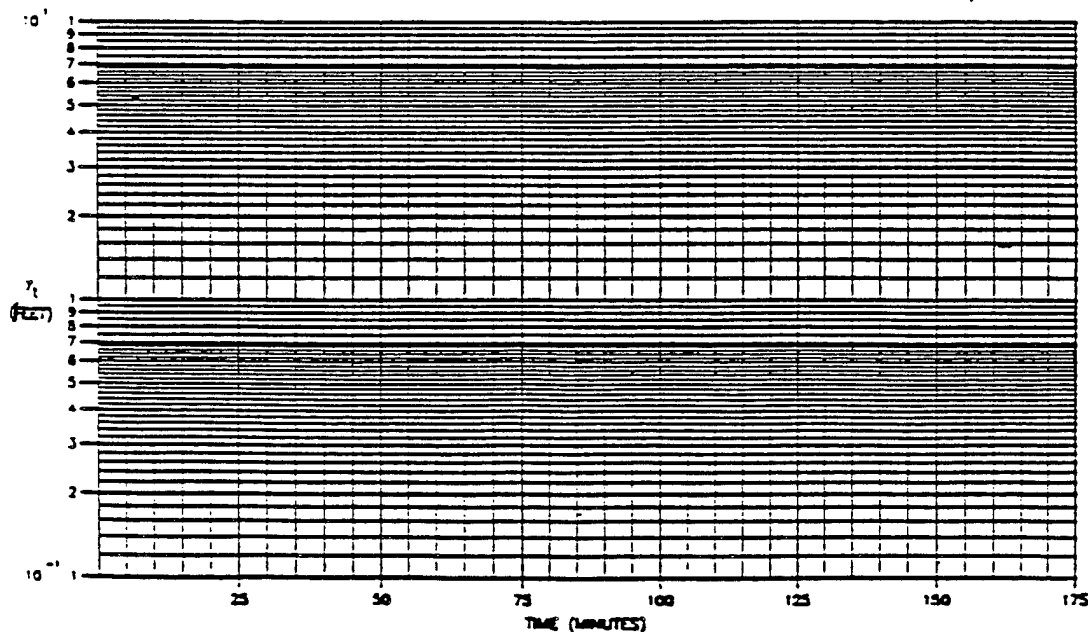
[illegible]

WHERE:  $\sigma'_c = [(1-n)r_c^2 + nr_c^2]$   
 $n$  = POROSITY (-30%)

- $r_p$  TAKES INTO ACCOUNT THE RADIUS OF THE WELL AND THE THICKNESS AND POROSITY OF THE GRAVEL PACK. POROSITY OF THE GRAVEL PACK ( $\alpha$ ) IS ESTIMATED AS JOE. USE THIS EQUATION IF A GRAVEL PACK IS PRESENT.

$$\text{ASSUME } L_w = 10 \text{ in } \frac{R_w}{r_w} = \left[ \frac{1.1}{\ln(L_w/r_w)} + \frac{C}{(L_w/r_w)} \right]^{-1} \quad C = 1.4$$

ASSUME  $L_0 < H$ :  $\ln \frac{R_2}{r_w} = \left[ \frac{1.1}{\ln(L_0/r_w)} + \frac{A + B \ln[(H-L_0)/r_w]}{(L_0/r_w)} \right]^{-1}$

**FIGURE 3.12**

## BOUWER AND RICE ANALYSIS DATA FORM

**Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska**

**ENGINEERING-SCIENCE, INC.**

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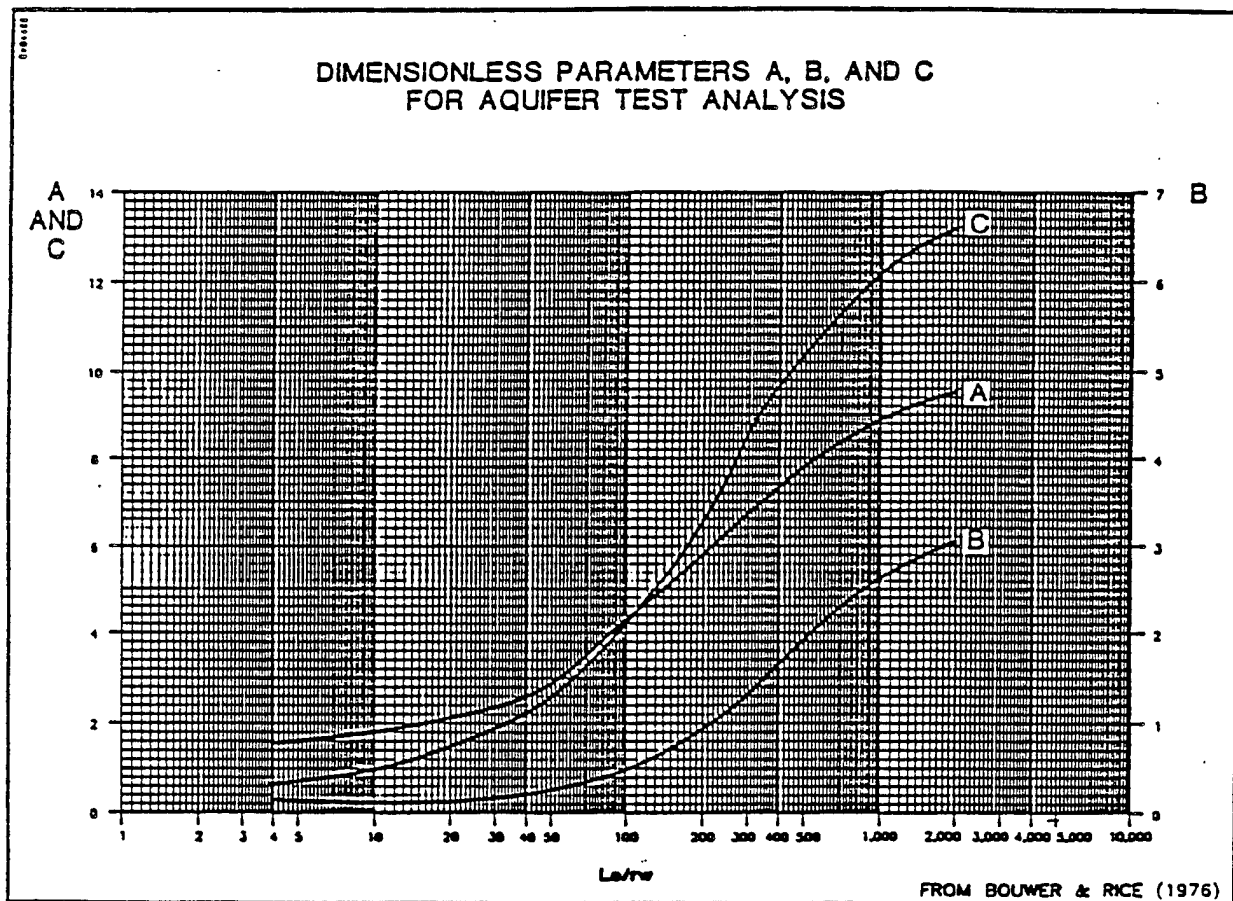


FIGURE 3.13

**DIMENSIONLESS PARAMETER**

Intrinsic Remediation EE/CA  
Offutt Air Force Base, Nebraska

**ENGINEERING-SCIENCE, INC.**

Denver, Colorado

## SECTION 4

### REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of field work, the Bioplume II numerical ground water model will be used to determine the fate and transport of fuel hydrocarbons dissolved in ground water at the site. Based upon model predictions of contaminant concentrations and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed. If it is shown that intrinsic remediation of BTEX compounds at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at this site, institutional controls such as ground water or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, free-product recovery, ground water pump-and-treat, enhanced biological treatment, bioventing, air sparging, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II model. The model will then be used to predict the BTEX plume (and risk) reduction that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, an EE/CA report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II model simulations developed for this site.

**TABLE 4.1**  
**EXAMPLE EE/CA REPORT OUTLINE**  
**INTRINSIC REMEDIATION EE/CA**  
**OFFUTT AIR FORCE BASE, NEBRASKA**

---

**INTRODUCTION**

**SITE DESCRIPTION**

- Background
- Soil and Ground Water Characteristics
- Site Contamination

**IDENTIFICATION OF REMEDIATION OBJECTIVES**

- Potential Pathways for Human/Ecological Receptor Exposure
- Chemical-Specific Applicable or Relevant and Appropriate requirements

**DESCRIPTION OF REMEDIATION ALTERNATIVES**

- Intrinsic Remediation/Long-Term Monitoring
- Alternative 2 (Site Specific)
- Alternative 3 (Site Specific)

**ANALYSIS OF REMEDIATION ALTERNATIVES**

- Effectiveness (Bioplume II Model Results and Discussion)
- Implementability
  - Technical
  - Administrative (Political)
- Cost
  - Capital Costs
  - Operating Costs
  - Present Worth Cost

**RECOMMENDED REMEDIATION APPROACH**

- How does the recommended technology offer adequate protection for less cost.

**APPENDICES: Supporting Data and Documentation**

- Site-Specific Bioplume II Model Input and Results

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## SECTION 5

### QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field, and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to an onsite or offsite analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., ground water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used and packaged in coolers with ice to maintain a temperature of 4 °C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

One duplicate sample will be collected for every 10 or fewer samples collected, both for ground water and soils. Volume permitting, duplicate samples will be collected at locations where low to moderate levels of contamination are believed to be present.

One rinseate sample will be collected for every 10 or fewer ground water samples collected from existing wells. If disposable bailers are used for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a new disposable bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs by Methods SW8020 and/or SW8240.

A field blank will be collected for every 20 or fewer ground water samples (both from ground water monitoring point and existing ground water monitoring well sampling events) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container

**TABLE 5.1**  
**QA/QC SAMPLING PROGRAM**  
 INTRINSIC REMEDIATION EE/CA  
 OFFUT AIR FORCE BASE, NEBRASKA

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates	7 Ground Water and 2 Soil Samples (10%)	VOCs, TPH
Rinseate Blanks	7 Samples (10% of Ground Water Samples)	VOCs
Field Blanks	4 Samples (5 % of Ground Water Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)



while sampling activities are underway. The field blank will be analyzed for VOCs by Methods SW8020 and/or 8240.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

## SECTION 6

### REFERENCES

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- Woodward-Clyde Consultants (W-C), 1992b, *Installation Restoration Program, Groundwater Monitoring Program 1991-1992, Offutt Air Force Base, Omaha, Nebraska*, November.

## **APPENDIX A**

### **CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR GROUND WATER SAMPLES**

**Appendix A - Soil, Soil Gas, and Ground Water Analytical Protocol**

<b>Matrix</b>	<b>Analysis</b>	<b>Method/Reference</b>	<b>Comments</b>	<b>Data Use</b>	<b>Recommended Frequency of Analysis</b>	<b>Sample Volume, Sample Container, Sample Preservation</b>	<b>Field or Fixed-Base Laboratory</b>
Soil	Volatile organics	Gas chromatography/mass spectrometry method SW8240	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap, cool to 4°C	Fixed-base
Soil	Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]); trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil, the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap, cool to 4°C	Fixed-base

Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field

# Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous ( $\text{Fe}^{+2}$ )	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Water	Ferrous ( $\text{Fe}^{+2}$ )	Colorimetric HACH 25140-25	Alternate method; field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field

Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Chloride	Mercuric nitrate titration A4500-Cl <sup>-</sup> C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model, concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles, analyze immediately, alternately, measure dissolved oxygen <i>in situ</i>	Field
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container, analyze immediately	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	A2320, titrimetric, E310.2, colorimetric	Handbook method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 250 mL of water in a glass or plastic container, analyze within 6 hours	Field



Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Nitrate ( $\text{NO}_3^-$ )	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Sulfate ( $\text{SO}_4^{2-}$ )	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate ( $\text{SO}_4^{2-}$ )	HACH SulfaVer 4 method	Photometric	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Water	Dissolved sulfide ( $\text{S}^{2-}$ )	Hach Model HS-C test kit	Procedure uses reagent-impregnated test strips to determine sulfide species (except insoluble metal sulfides) in the 0 to 5 mg/L range	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field

Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Methane, carbon dioxide	RSKSOP-114 modified to analyze water samples for methane and carbon dioxide by headspace sampling with dual thermal conductivity and flame ionization detection (also, see reference in note 10)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps; cool to 4°C	Fixed-base

Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are contaminants suspected of undergoing biological transformation	Ethane and ethene are products of the biotransformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	N/A	Field

Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEx, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEx, which is the primary target analyte for monitoring natural attenuation; BTEx concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEx) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons—collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons—collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

Appendix A (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons, reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2, cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240	Handbook method	Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A3310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base

#### Appendix A (Concluded)

##### NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to Robert S. Kerr (*Environmental Protection Agency Laboratory*) *Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

**APPENDIX B**

**AVAILABLE SOIL AND GROUND WATER ANALYTICAL  
RESULTS**

FACILITY 6275 - TANK 349  
OFFUTT AFB, NEBRASKA

Field Screening of Soil Samples  
(Parts Per Million)

Depth (feet)	MW 349-1	MW 349-2	MW 349-3	MW 349-4	MW 349-5	MW 349-6	MW 349-7	MW 349-8	MW 349-9	MW 349-10	MW 349-11	MW 349-12	MW 349-13	MW 349-14
3.0-5.0	36	<1	<1	<2	2	<1	<1	<1	<1	<1	<1	<1	<1	<1
8.0-10.0	150	720	<1	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
13.0-15.0	260	1320	<1	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1
18.0-20.0	240	530	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
23.0-25.0	320	510	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
28.0-30.0	470	460	<1	<1	<1	<1	<1	7	<1	<1	<1	<1	<1	<1
33.0-35.0	1440	510	<1	<1	<1	<1	<1	170	<1	<1	<1	<1	<1	<1
38.0-40.0	1240	550	<1	<1	<1	1020	320	1300	18	<1	<1	<1	<1	<1
43.0-45.0	-	1410	-	<1	<1	760	280	1060	7	<1	<1	6	<1	<1
48.0-50.0	-	840	-	-	-	-	-	-	-	-	-	-	<1	<1
53.0-55.0	-	-	-	-	-	-	-	-	-	-	-	-	<1	-

Notes:

An Organic Vapor Meter (OVM) was used.

- = Boring not advanced to the reported depth.

Source: Terracon, 1994



FACILITY 6275 - TANK 349  
OFFUTT AFB, NEBRASKA

Summary of Groundwater Analysis  
(micrograms/liter  $\mu\text{g/L}$ )

Monitoring Well	Benzene	Toluene	Ethyl Benzene	Xylene	TRPH
MW 349-1	Free product observed, no tests.				
MW 349-2	Free product observed, no tests.				
MW 349-3	<2	<2	<2	2.6	<1,000
MW 349-4	<2	<2	<2	<2	<1,000
MW 349-5	<2	<2	<2	<2	<1,000
MW 349-6	43,000	3,800	42,000	14,000	190,000
MW 349-7	32,000	3,300	34,000	17,000	40,000
MW 349-8	21,000	3,800	31,000	14,000	47,000
MW 349-9	<2	<2	<2	<2	1,300
MW 349-10	<2	<2	<2	<2	<1,000
MW 349-11	2.5	4.3	13	17	<1,000
MW 349-12	<2	<2	<2	<2	<1,000
MW 349-13	<2	<2	<2	<2	<1,000
MW 349-14	<2	<2	<2	2.7	<1,000

Notes: BTEX - Benzene, Toluene, Ethyl Benzene, Xylene

TRPH - Total Recoverable Petroleum Hydrocarbons

Samples from MW locations collected from developed monitoring wells.

Source: Terracon, 1994

TABLE 4.11  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL AND SEDIMENT SAMPLES  
FROM FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft)	Volatiles Organics SW3539/E276(mg/Kg)	Semivolatiles Organics SW3539/E276(mg/Kg)	Petroleum Hydrocarbons SW3539/E418.1(mg/Kg)	Trace Metals SW1319/6916/7664, 7478 & 7748,(mg/Kg)	Percent Moisture %
<b>Soil Samples:</b>							
OF-FPTA3-SB1-SS1-2	08-25-88	2	Benzene - 2,800 Toluene - 940 Ethylbenzene - 3,200 Styrene - 35 Total Xylenes - 18,000 Ethyl methacrylate - 2,000	Naphthalene - 1,800 2-Methylnaphthalene - 1,600	15,000	NA	17.3
OF-FPTA3-SB1-SS2-5	08-25-88	5	Total Xylenes - 380	Naphthalene - 750 Fluorene - 440 Peanthrene - 960 2-Methylnaphthalene - 2,800	910	NA	22.7
OF-FPTA3-SB1-SS3-8	08-25-88	8	Acetone - 4,600(B)	2-Methylnaphthalene - 7	1,500	NA	17.9
OF-FPTA3-SB1-SS4-10	08-25-88	10	NA	ND	<100	NA	17.7
OF-FPTA3-SB1-SS5-11	08-25-88	11	Acetone - 5,100	ND	<100	NA	22.5
OF-FPTA3-MW1-SS1-6	08-29-88	6	ND	NA	<100	Ag - <1.0(N) Cr - 9.6 As - 55(W) Hg - <0.1 Ba - 186 Pb - 6.2 Cd - <1.0 Se - <0.5(W)	12.6
OF-FPTA3-MW1-SS2-9	08-29-88	9	ND	NA	<100	Ag - <1.0(N) Cr - 10.5 As - 4.3 Hg - <0.1 Ba - 164 Pb - 6.0 Cd - 1.2 Se - <0.5	10.7

Source: ES, 1990a

TABLE 4.11 (Continued)  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL AND SEDIMENT SAMPLES  
FROM FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft)	Volatile Organics SW5039/1246(mg/kg)	Semivolatile Organics SW3559/1276(mg/kg)	Petroleum Hydrocarbons SW3559/1418.1(mg/kg)	Trace Metals SW1319/6918,7669, 7478 & 7748(mg/kg)
OR-PPTA3-MW1-SS3-12	08-29-88	12	Acetone - 2,200	NA	25,000	
OR-PPTA3-MW2-SS1-6	09-06-88	6	ND	NA	<100	NA
OR-PPTA3-MW2-SS2-9	09-06-88	9	ND	NA	<100	NA
OR-PPTA3-MW3-SS1-6	09-06-88	6	NA	ND	NA	NA
OR-PPTA3-MW3-SS2-9	09-06-88	9	NA	ND	NA	NA
OR-PPTA3-MW4-SS1-6	09-06-88	6	ND	NA	<100	NA
OR-PPTA3-MW4-SS1-9	09-06-88	9	ND	NA	<100	NA
OR-PPTA3-MW4-SS1-12	09-06-88	12	ND	NA	<100	NA
OR-PPTA3-MW5-SS2-9	09-25-88	9	ND	ND	NA	NA
OR-PPTA3-MW5-SS1-6	09-29-88	6	ND	NA	<100	NA
OR-PPTA3-MW5-SS3-12 (Coded Field Duplicate of OR-PPTA3-MW5-SS1-6)	09-29-88	12	ND	NA	<100	NA

Source: ES, 1990a

TABLE 4.11 (Continued)  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL AND SEDIMENT SAMPLES  
FROM FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft)	Volatile Organics SW5339/E244(wg/kg)	Semivolatile Organics SW3559/E276(wg/kg)	Petroleum Hydrocarbons SW3559/E418.1(mg/kg)	Trace Metals SW1316/4018,7664, 7478 & 7744.(mg/kg)
<b>Sediment Samples</b>						
OP-FPTA3-W1-SED1	11-09-88		Dichloromethane - 42(G)	NA	480	NA
OP-FPTA3-W2-SED1	11-10-88		Benzene - 790/ND Toluene - 1,700(F)/2,000(D) Total Xylenes - 1,800/2,800(D) Dichloromethane - 54(G)/1,400(G,D)	NA	49,000	NA
OP-FPTA3-W3-SED1 (Coded Field Duplicate of OP-FPTA3-W2-SED1)	11-10-88		Benzene - 980/ND Toluene - 2,000(F)/1,500(D) Total Xylenes - 4,900(F)/5,200(D) Dichloromethane - ND/1,000(G,D)	NA	61,000	NA
OP-11F6-W1-SED1 (Drainage from FPTA3 discharge pond)	11-09-88		Ethylbenzene - 17 Total Xylenes - 110	Naphthalene - 1,000 Fluorene - 8,400 Phenanthrene - 52,000 Pyrene - 890 Bis(2-ethylhexyl)phthalate - 610 2-Methylnaphthalene - 38,000	NA	

NA - Not Analyzed

ND - None Detected

(G) - The analyte is found in the associated blank as well as in the sample.

(N) - Spiked sample recovery not within control limits.

(W) - Post digestion spike for Furnace AA analysis out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

Note: Dichloromethane and/or acetone were detected in the method blank. See test for discussion.

Source: ES, 1990a

TABLE 4.12  
SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER AND SURFACE WATER SAMPLES  
FROM FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Volatile Organics* SW8260(mg/L)	Semivolatile Organics SW8270(mg/L)	Petroleum Hydrocarbons E151(mg/L)	Common Anions* A433(mg/L)	Dissolved Solids E160.1(mg/L)	Trace Metals* E200.7, E204.2, E239.2, E245.1 & E270.2(mg/L)
<b>Groundwater:</b>							
OP-PPTA3-W1-GW1	10-27-88	Chloroform - 6	ND	ND	Chloride - 17.2 Sulfate - 49.2	606	Ba - 2.0    Na - 263 Ca - 100    Pb - <0.005(W) K - 6.9
OP-PPTA3-W2-GW1	11-03-88	ND	NA	1.3	NA	2600	NA
OP-PPTA3-W3-GW1	10-27-88	ND	ND	ND	Chloride - 5.9 Sulfate - 5.2	540	As - 0.081    K - 7.3 Ba - 0.31    Na - 10.7 Ca - 133
OP-PPTA3-W4-GW1	11-02-88	ND	NA	1.3	NA	545	NA
OP-PPTA3-W5-GW1	11-03-88	ND	NA	ND	NA	684	NA
OP-PPTA3-W6-GW1 (Coded Field Duplicate of	10-27-88	Chloroform - 5	Diethyl phthalate - 13	ND	Chloride - 15.1 Sulfate - 44.9	744	Ag - <0.01(N)    Na - 75 Ca - 43.6    Pb - 0.20(S) K - 8.3
OP-PPTA3-W2-SW1	11-10-88	Benzene - 180 Toluene - 490 Ethylbenzene - 87 Total Xylenes - 380	NA	2.5	NA	NA	NA

Source: ES, 1990a

TABLE 4.12 (Continued)  
SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER AND SURFACE WATER SAMPLES  
FROM FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Volatile Organics SW8240(mg/L)	Semivolatile Organics SW8274(mg/L)	Polycyclic Aromatic Hydrocarbons E1818.1(mg/L)	Common Anions A439(mg/L)	Dissolved Solids E164.1(mg/L)	Trace Metals** E206.7, E206.2, E239.2, E245.1 & E278.2(mg/L)
OR-PPTA3-W3-SW1 (Coded Field Duplicate of OR-PPTA3-W2-SW1)	11-10-88	Benzene - 160 Toluene - 470 Ethylbenzene - 79 Total Xylenes - 350	NA	3.0	NA	NA	NA
OR-HFR-W1-SW1 (Obtained from PPTA3 discharge pond)	11-09-88	ND	Bis(2-ethylhexyl)- phthalate - 17(G)	NA	Chloride - 8.5 Fluoride - 0.28(N) Sulfate - 54	NA	Ag - <0.01(N) Ca - 52.6 As - 0.0055(W, K - 27.8 Ba - 0.06(B) Na - 9.6
OR-HFR-W3-SW1 (Coded Field Duplicate of OR-HFR-W1-SW1)	11-09-88	ND	Bis(2-ethylhexyl)- phthalate - 20(G)	NA	Chloride - 8.5 Fluoride - 0.28(N) Nitrate - 0.46 Sulfate - 54.3	NA	Ag - <0.01(N) K - 27.6 Ba - 0.066(B) Na - 8.8 Ca - 53.0 Pb - 0.005(W)

NA - Not Analyzed

ND - None Detected

(N) - Spiked sample recovery not within control limits.

(S) - Reported value was determined by the Method of Standard Additions.

(W) - Post digestion spike for Furnace AA analysis out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

\* - MCLs (mg/L): chloroform-100 (Nebraska); benzene-5

\*\* - MCLs (mg/L): sulfate-250 (Nebraska); nitrate-10 (Nebraska); barium-1.0, arsenic-0.05, lead-0.05

Source: ES, 1990a

**TABLE A.3**  
**SUMMARY OF ANALYTICAL RESULTS FOR**  
**MONITORING WELL SAMPLING AT FPTA-3**  
**OFFUTT AIR FORCE BASE**

Sample Identifier	Date Collected	Halogenated Volatile Organic Compounds (SW8010) (µg/L)	Aromatic Volatile Organic Compounds (SW8020) (µg/L)	Petroleum Hydrocarbons (E418.1)(µg/L)	Dissolved Metals (Ba,Pb,As)(mg/L)
OF-FPTA3-W1-GW2	8-10-89	Methylene Chloride -15 (Dichloromethane)	ND	ND	Ba-0.36
OF-FPTA3-W2-GW2	8-10-89	ND	Benzene-5.7 Ethylbenzene-4.0 Xylenes (total) -3.0	ND	Ba-0.33
OF-FPTA3-W3-GW2	8-10-89	ND	ND	ND	As-0.073 Pb-0.005 Ba-0.39
OF-FPTA3-W4-GW2	8-10-89	ND	ND	ND	Ba-0.17
OF-FPTA3-W5-GW2	8-10-89	ND	ND	ND	As-0.011 Ba-0.25
OF-FPTA3-W6-GW2 (Field duplicate of OF-FPTA3-W2-GW2)	8-10-89	ND	Benzene-6.3 Ethylbenzene-4.1 Xylenes (total) -4.6	ND	Ba-0.33
OF-FPTA3-MW6	11/29/89	Chloroform-1.0	Toluene-10.0	ND	As-0.012 Ba-0.37

ND - Not detected.

Explanation of sample identifier: OF-FPTA3-W1-GW2; Offutt AFB, Fire Protection Training Area 3, Monitoring Well 1, second groundwater sample. OF-FPTA3-MW6 was installed in Fall 1989.

Source: ES, 1990a

**TABLE A.6**  
**SUMMARY OF SOIL SAMPLING AT FPTA-3**  
**OFFUTT AIR FORCE BASE**

Sample Identifier	Date Collected	Halogenated Volatile Organic Compounds (SW8010) (µg/kg)	Aromatic Volatile Organic Compounds (SW8020) (µg/kg)
OF-FPTA3-BH2-SS1	11/15/89	Trichloroethene-134	Ethyl Benzene-760 Toluene-1,060 Xylenes (total)-2,600
OF-FPTA3-BH3-SS1	11/15/89	Dichloromethane- 86B	Ethyl Benzene-170 Toluene-42 B Xylene (total) -220
OF-FPTA3-BH4-SS1	11/15/89	1,1-Dichloroethane-58 1,2-Dichloroethane-69 1,2-Dichloroethene-430 Dichloromethane - 63 B Tetrachloroethene-16 1,1,1-Trichloroethane-73 B	Benzene-15 Ethyl Benzene-17 Toluene-76 B Xylenes (total) - 68
OF-FPTA3-BH5-SS1	11/16/89	1,1-Dichloroethane-4.8 1,2-Dichloroethane-12 1,2-Dichloroethene-122 Dichloromethane - 22 B Trichloroethene-5.4	Benzene-14 Ethyl Benzene-140 Toluene-71 B Xylenes (total) - 320

B - The analyte is found in the associated blank as well as in the sample.

Source: ES, 1990a



**TABLE 1**  
**SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES**  
**FIRE PROTECTION TRAINING AREA 3**  
**OFFUTT AIR FORCE BASE**

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatile Organics SW5030/8240 (µg/kg)	Volatile Organics Dilution Factor	Semivolatile Organics SW3550/8270 (µg/kg)	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
OR-FPTA3-AU1-2	6/28/90	2 960	8.01	Methylene Chloride - 38,000 B Acetone - 41,000 J, B Toluene - 30,000 Ethylbenzene - 120,000 m/p-Xylene - 170,000 o-Xylene - 67,000	20	Naphthalene - 2,600 2-Methylnaphthalene - 3,600 Phenanthrene - 260 J	2	Ag-ND As-6.1 N, S, J Ba-174 UJ Cd-ND Cr-12.7 UJ Hg-ND Pb-8.3 Se-ND	9
OR-FPTA3-AU1-4	6/28/90	4 958	7.56	Methylene Chloride - 29,000 B Acetone - 49,000 J, B Ethylbenzene - 22,000 m/p-Xylene - 42,000	20	Naphthalene - 8,200 2-Methylnaphthalene - 14,000 Fluorene - 1,100 J Phenanthrene - 2,000 J	5	Ag-ND As-13.9 N, S, J Ba-239 UJ Cd-ND Cr-26.5 UJ Hg-ND Pb-15.8 UJ Se-0.20 B, N, J	26
OR-FPTA3-AU2-2	6/28/90	2 960	7.87	Methylene Chloride - 63 B	1	Di-n-Butylphthalate - 550	1	Ag-ND As-7.1 N, S, J Ba-187 UJ Cd-ND Cr-11.3 UJ Hg-ND Pb-8.3 UJ Se-ND	12
OR-FPTA3-AU2-4	6/28/90	4 958	7.72	Methylene Chloride - 150 B Acetone - 220 J	5	2-Methylnaphthalene - 240 J Di-n-Butylphthalate - 940	1	Ag-ND As-5.3 N, S, J Ba-363 UJ Cd-0.56 J, UJ Cr-29.4 UJ Hg-ND Pb-15.1 UJ Se-ND	18

TABLE 1-Continued  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatile Organics SW5030/8240 (µg/kg)	Volatile Organics Dilution Factor	Semivolatile Organics SW3550/8270 (µg/kg)	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
OF-FPTA3-AU3-2	6/29/90	2 960	7.30	Methylene Chloride - 44,000 B	20	2-Methylnaphthalene - 2,800 Dibenzofuran - 930 Fluorene - 1,500 Phenanthrene - 3,400 Fluoranthene - 100 J Pyrene - 79 J	1	Ag-ND As-5.2 B,N,J Ba-178 UJ Cd-ND Cr-16.8*,UJ Hg-ND Pb-14.3 UJ Se-0.17 B,W,J	18
OF-FPTA3-AU3-4	6/29/90	4 958	7.44	Methylene Chloride - 17,000 B Acetone - 43,000 J, B	20	Naphthalene - 750 2-Methylnaphthalene - 3,300 Dibenzofuran - 550 Fluorene - 810 Phenanthrene - 1,500	1	Ag-ND As-4.9 B,N,J Ba-174 UJ Cd-ND Cr-15*,UJ Hg-ND Pb-11 UJ Se-0.24 B,W,J	20
OF-FPTA3-AU3A-4 (duplicate of OF-FPTA3-AU3-4)	6/29/90	4 958	7.42	Methylene Chloride - 19,000 B Acetone - 55,000 J, B	20	Naphthalene - 920 2-Methylnaphthalene - 4,200 Dibenzofuran - 400 J Fluorene - 400 J Phenanthrene - 1,100	1	Ag-ND As-4.3 N,S,J Ba-167 UJ Cd-ND Cr-15.2*,UJ Hg-ND Pb-9 UJ Se-0.17,B,J	20
OF-FPTA3-AU5-2	6/28/90	2 960	7.82	Methylene Chloride - 310 B Acetone - 190 J	5	Di-n-Butylphthalate - 520	1	Ag-ND As-8.1 B,N*,J Ba-189 UJ Cd-ND Cr-14.2 UJ Hg-ND Pb-10.3 UJ Se-ND	12

TABLE 1-Continued  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatiles Organics SW5030/8240 (µg/kg)	Volatiles Organics Dilution Factor	Semivolatile Organics SW3550/8270 (µg/kg)	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
OF-FPTA3-AU5-6	6/28/90	<u>6</u> 956	7.20	Methylene Chloride - 17,000 B Acetone - 43,000 J, B	20	Naphthalene - 95 J 2-Methylnaphthalene - 150 J Di-n-Butylphthalate - 820	1	Ag-ND As-8.3 B,N,* J Ba-224 UJ Cd-0.75 * UJ Cr-18.8 UJ Hg-ND Pb-11.2 UJ Se-ND	24
OF-FPTA3-AU6-2	6/28/90	<u>2</u> 960	7.89	Acetone - 40,000 J, B m/p - Xylene - 8,300 J o-Xylene - 3,900 J	20	2-Methylnaphthalene - 4,900 Phenanthrene - 960 J Di-n-Butylphthalate - 870 J	5	Ag-ND As-6.1 N,* S,J Ba-171 UJ Cd-ND Cr-13.9 UJ Hg-ND Pb-11.1 UJ Se-ND	10
OF-FPTA3-AU6-4	6/28/90	<u>4</u> 958	7.46	Methylene Chloride - 16,000 J, B Toluene - 4,900 J Ethylbenzene - 35,000 m/p-Xylene - 100,000 o-Xylene - 42,000	20	Naphthalene - 1,300 2-Methylnaphthalene - 2,000 Phenanthrene - 190 J Di-n-Butylphthalate - 1,300	1	Ag-ND As-7.4 N,* S,J Ba-215 UJ Cd-ND Cr-22.2 UJ Hg-ND Pb-17.9 S,UJ Se-0.02 B,N,J	25
OF-FPTA3-AU7-2	6/29/90	<u>2</u> 962	7.90	Methylene Chloride - 16 B,UJ 1,1-Dichloroethane - 6 J trans-1,2 - Dichloroethene - 65 1,1,1-Trichloroethane - 4 J Trichloroethene - 58 Toluene - 10	1	ND	1	Ag-ND As-10.5 N,* S,J Ba-191 UJ Cd-0.72, * Cr-33.7 UJ Hg-0.092,B Pb-21.4 Se-0.30 B,N,W,J	17

TABLE 1-Continued  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatiles Organics SW5030/8240 (µg/kg)	Volatiles Organics Dilution Factor	Semivolatile Organics SW3550/8270 (µg/kg)	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
OF-FPTA3-AU7-6	6/29/90	6 958	8.00	Methylene Chloride - 130 B 1,1-Dichloroethane - 23 trans-1,2-Dichloroethene - 200 1,1,1-Trichloroethane - 16 Trichloroethene - 170 Toluene - 64	1	Di-n-Butylphthalate - 160 J	1	Ag-ND As-7.2 N*,S,J Ba-232 UJ Cd-ND Cr-18.1 UJ Hg-ND Pb-12.7 UJ Se-ND	20
OF-FPTA3-AU7-10	6/29/90	10 954	8.09	Methylene Chloride 46 B,UJ Acetone - 25 J 1,1-Dichloroethene - 21 trans-1,2-Dichloroethene - 160 1,1,1-Trichloroethane - 8 Trichloroethene - 89 Toluene - 19	1	ND	1	Ag-ND As-3.4 N*,J Ba-156 UJ Cd-ND Cr-10.4 UJ Hg-ND Pb-6.2 UJ Se-ND	12
OF-FPTA3-AU8-2	6/29/90	2 962	7.58	Methylene Chloride - 45 B,UJ Acetone - 91 J Trichloroethene - 9 Toluene - 33	1	ND	1	Ag-ND As-8.7 B,N*,J Ba-193 UJ Cd-ND Cr-24.5 UJ Hg-ND Pb-16.7 UJ Se-0.14 B,N,W,J	16
OF-FPTA3-AU8-6	6/29/90	6 958	7.85	Methylene Chloride - 49 B,UJ Acetone - 140 trans-1,2-Dichloroethene - 16 1,1,1-Trichloroethane - 4 J Trichloroethene - 23 Toluene - 39	1	ND	1	Ag-ND As-7.9 N*,S,J Ba-251 UJ Cd-ND Cr-19.2 UJ Hg-ND Pb-13 UJ Se-ND	20

Source: ES, 1990b

906J210

TABLE 1-Continued  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatiles Organics SW5030/8240 (µg/kg)	Volatiles Organics Dilution Factor	Semivolatiles Organics SW5550/8270 (µg/kg)	Semivolatiles Organics Dilution Factor	Trace Metals SW1310/6010/7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
OF-FTTA3-AU8-10	6/29/90	10 954	8.17	Methylene Chloride - 20 B, UJ Acetone - 45 J trans-1,2-Dichloroethene - 12 1,1,1-Trichloroethane - 3 J Trichloroethene - 18 Toluene - 33	1	ND	1	Ag-ND As-3.7 N, S, J Ba-140 UJ Cd-ND Cr-9.5 UJ Hg-ND Pb-6.3 UJ Se-ND	20
OF-FTTA3-AU9-2	6/29/90	2 962	7.97	Methylene Chloride - 9,400 Acetone - 13,000 J, B Trichloroethene - 5,200 Toluene - 1,200 J Ethylbenzene - 700 J o-Xylene - 1,200 J	2	Diethylphthalate - 280 J Di-n-Butylphthalate - 320 J	1	Ag-ND As-2.1 N, S, J Ba-167 UJ Cd-3.2 S, UJ Cr-22 UJ Hg-ND Pb-329 Se-0.12 B, N, W, UJ	6
OF-FTTA3-AU9-6	6/29/90	6 958	7.91	Methylene Chloride - 13,000 Acetone - 14,000 J, B m/p-Xylene - 710 J o-Xylene - 430 J	2	Naphthalene - 210 J 2-Methylnaphthalene - 470 Di-n-Butylphthalate - 100 J, B	1	Ag-ND As-5.9 N, S, J Ba-144 UJ Cd-ND Cr-9.9 UJ Hg-ND Pb-33.4, S Se-ND	18
OF-FTTA3-AU9A-6 (duplicate of OF-FTTA3-AU9-6)	6/29/90	6 958	7.93	Methylene Chloride - 14,000 Acetone - 11,000 J, B Toluene - 800 J Ethylbenzene - 550 J o-Xylene - 1,100 J	2	2,4-Dimethylphenol - 120 J Naphthalene - 220 J 2-Methylnaphthalene - 460	1	Ag-ND As-3.7 N, S, J Ba-197 UJ Cd-ND Cr-13.5 UJ Hg-ND Pb-34.7 Se-ND	9

Source: ES, 1990b

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TABLE 1-Continued  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatile Organics SW5030/8240 (µg/kg)	Volatile Organics Dilution Factor	Semivolatile Organics SW3550/8270 (µg/kg)	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/kg)	Percent Moisture %
Soil Samples:									
OF-FPTA3-AU9-10	6/29/90	10 954	7.98	Methylene Chloride - 9,400 Acetone - 13,000 J, B Trichloroethene - 480 J m/p-Xylene - 1,000 J o-Xylene - 530 J	2	ND	1	Ag-ND As-5.6 N, S, J Ba-112 UJ Cd-ND Cr-12 UJ Hg-ND Pb-10.2 UJ Se-ND	20
OF-FPTA3-AU10-2	6/29/90	2 961	8.06	Methylene Chloride - 18 B UJ Acetone - 19 J trans-1,2-Dichloroethene - 5 J Trichloroethene - 4 J	1	ND	1	Ag-ND As-7.5 N, S, J Ba-158 UJ Cd-0.55 UJ Cr-17.3 UJ Hg-ND Pb-12.7 UJ Se-0.15 B, N, W, J	14
OF-FPTA3-AU10-6	6/29/90	6 975	7.79	Methylene Chloride - 14 B Acetone - 27 J	1	ND	1	Ag-ND As-7.2 N, S, J Ba-169 UJ Cd-0.62 UJ Cr-13.6 UJ Hg-0.04, B Pb-10.9 UJ Se-ND	13
OF-FPTA3-AU10-10	6/29/90	10 953	7.25	Methylene Chloride - 11,000 Acetone - 12,000 J, B	2	Naphthalene - 97 J 2-Methylnaphthalene - 250 J Phenanthrene - 75 J bis(2-Ethylhexyl)Phthalate - 51 J	1	Ag-ND As-8.8 B, N, J Ba-209 UJ Cd-ND Cr-13.7 UJ Hg-0.065 Pb-14.6 UJ Se-0.23 B, J	25
OF-FPTA3-AU11-2	6/29/90	2 961	7.97	Methylene Chloride - 12 B, UJ Acetone - 25 J	1	bis(2-Ethylhexyl)Phthalate - 44 J	1	Ag-ND As-7.3 B, N, J Ba-180 UJ Cd-ND Cr-13.6 UJ Hg-0.053 B Pb-22.5 S Se-0.25 B, J	18

Source: ES, 1990b

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TABLE 1-Continued  
SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatile Organics SW5030/8240 (µg/kg)	Volatile Organics Dilution Factor	Semivolatile Organics SW5550/8270 (µg/kg)	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
OR-FPTA3-AU11-6	6/29/90	6 957	7.61	Methylene Chloride - 6,100 Acetone - 14,000 J, B	2	Naphthalene - 1,600 J 2-Methylnaphthalene - 11,000 Fluorene - 1,600 J Phenanthrene - 4,700	5	Ag-ND As-6.4 B,N,J Ba-204 UJ Cd-ND Cr-16.5 *UJ Hg-ND Pb-15.6 S,UJ Se-0.25 B,W,J	21
OR-FPTA3-AU11-10	6/29/90	10 953	7.92	Methylene Chloride - 8,300 Acetone - 11,000 J, B	2	2-Methylnaphthalene - 350 J Fluorene - 120 J Phenanthrene - 360 J	1	Ag-ND As-5.5 N,J Ba-387 UJ Cd-ND Cr-10.9 *UJ Hg-ND Pb-7 S,UJ Se-ND	11
OR-FPTA3-AU11A-10 (duplicate of OR-FPTA3-AU11-10)	6/29/90	10 953	8.04	Methylene Chloride - 15,000 B	20	2-Methylnaphthalene - 360 J Fluorene - 120 J Phenanthrene - 400	1	Ag-ND As-4.7 N,J Ba-253 UJ Cd-ND Cr-10.5 *UJ Hg-ND Pb-7.1, S,UJ Se-ND	11
<b>Trip Blanks</b>									
OR-FPTA3-TB2-AU	6/29/90	NA	NA	Methylene Chloride - 10 B Chloroform - 3 J	1	NA	1	NA	NA
OR-FPTA3-TB4-AU	6/29/90	NA	NA	Methylene Chloride - 12 Chloroform - 4 J	1	NA	1	NA	NA

Source: ES, 1990b

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**TABLE 1-Continued**  
**SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES**  
**FIRE PROTECTION TRAINING AREA 3**  
**OFFUTT AIR FORCE BASE**

Sample Identifier	Date Collected	Depth (ft) Elevation (MSL)	pH	Volatiles Organics SW5030/8240 ( $\mu\text{g/kg}$ )	Volatiles Organics Dilution Factor	Semivolatile Organics SW3550/8270 ( $\mu\text{g/kg}$ )	Semivolatile Organics Dilution Factor	Trace Metals SW1310/6010, 7060, 7470 & 7740 (mg/kg)	Percent Moisture %
<b>Soil Samples:</b>									
<b>Rinsates:</b>									
OF-FPTA3-R2	6/29/90	NA	NA	Methylene Chloride - 2 J, B	1	ND	1	Ag-ND As-ND Ba-480 Cd-32 Cr-144.0 Hg-ND Pb-4.2, N Se-ND	NA

ND Not Detected  
NA Not Analyzed

**Organic Parameters:**

The value reported is an estimated concentration. This is used when the compound is detected at an amount less than the reporting limit.  
The analyte is found in the associated blank as well as in the sample.  
The analyte is reported as not detected and the detection limit is estimated.

**Inorganic Parameters:**

Reported value is less than Reporting limit but greater than the IDL.  
Spiked sample recovery not within control limits.  
Reported value was determined by the Method of Standard Additions.  
Duplicate analysis not within control limits.  
Post digestion spike for Furnace AA analysis out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.  
The analyte is reported as not detected and the detection limit is estimated.

Note: There are no AU4 samples as no auger holes were designated AU4.

Source: ES, 1990b

AT099/908J88



**TABLE 2**  
**SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES**  
**FIRE PROTECTION TRAINING AREA 3**  
**OFFUTT AIR FORCE BASE**

Sample Identifier	Date Collected	pH	Volatiles Organics Dilution Factor	Volatiles Organics SW5030/8240 (µg/L)	Semivolatiles Organics SW3550/8270 (µg/L)	Semivolatiles Organics Dilution Factor	Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/L)	Trace Metals (Filtered) (µg/L)
<b>Groundwater:</b>								
FPTA3-MW1-GW3	6/27/90	7.24	1.0	ND	bis(2-Ethylhexyl)phthalate - 5 J,B	1.0	Ag - ND As - ND Ba - 352 Cd - ND Cr - 9.8 * Hg - ND Pb - 18 S,N Se - ND	NA
FPTA3-MW2-GW3	6/27/90	6.89	1.0	ND	bis(2-Ethylhexyl)phthalate - 5 J,B	1.0	Ag - ND As - 9.6 B Ba - 434 Cd - ND Cr - ND Hg - ND Pb - 32.5 S,N Se - ND	NA
FPTA3-MW3-GW3	6/27/90	7.17	1.0	ND	bis(2-Ethylhexyl)phthalate - 4 J,B	1.0	Ag - ND As - 224 Ba - 712 Cd - ND Cr - 18 * Hg - ND Pb - 39.7 S,N Se - ND	NA
FPTA3-MW4-GW3	6/28/90	7.19	1.0	ND	bis(2-Ethylhexyl)phthalate - 4 J,B	1.0	Ag - ND As - 9.9 B Ba - 254 Cd - ND Cr - 11 * Hg - ND Pb - 26.1 S,N Se - 1.5 B, W	NA
FPTA3-MW5-GW3	6/28/90	7.22	1.0	ND	bis(2-Ethylhexyl)phthalate - 5 J,B	1.0	Ag - ND As - 18.2 Ba - 315 Cd - ND Cr - ND Hg - ND Pb - 63.1 S,N Se - ND	NA

TABLE 2--Continued  
SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	pH	Volatile Organics		Volatile Organics SW5030/8240 (µg/L)	Semivolatile Organics		Trace Metals SW1310/6010,7060, 7470 & 7740 (mg/L)	Trace Metals (Filtered) (µg/L)
			Dilution	Factor		Dilution	Factor		
FPTA3-MW6A -GW3	6/28/90	7.17	1.0	1.0	ND	Benzoic Acid - 5 J bis(2-Ethylhexyl)phthalate-4 J,B	1.0	Ag - ND	Cr - ND
								As - 17.6	Ag - ND
								Ba - 431	As - 16.8
								Cd - ND	Pb - 15.5 N
FPTA3-MW10-GW3 (Duplicate of MW1)	6/27/90	7.17	1.0	1.0	ND	4-Chloro-3-Methylphenol-3 J Di-n-Butylphthalate-2 J bis(2-Ethylhexyl)phthalate-2 J	1.0	Ag - ND	Cr - ND
								As - 1.6 B	Hg - ND
								Ba - 357	Pb - 15.4 S,N
								Cd - ND	Se - ND
									NA

TABLE 2--Continued  
SUMMARY OF QUALITY CONTROL SAMPLES FOR  
FIELD AND TRIP BLANKS FOR GROUNDWATER SAMPLES  
FIRE PROTECTION TRAINING AREA 3  
OFFUTT AIR FORCE BASE

Sample Identifier	Date Collected	pH	Volatile Organics		Semi-volatile Organics		Volatile Organics		Semi-volatile Organics		Trace Metals		Trace Metals	
			Dilution Factor	(µg/L)	Dilution Factor	(µg/L)	SW5030/8240	(µg/L)	SW3550/8270	Dilution Factor	SW1310/6010,7060,7470 & 7740	(mg/L)	(Filtered) (µg/L)	
<b>Trip Blank:</b>														
FPTA3-TB1-GW3	6/28/90	NA	1.0	Chloroform - 4 J							NA	NA	NA	NA
<b>Rinsate:</b>														
FPTA3-R-GW3	6/28/90	NA	1.0	ND			bis(2-Ethylhexyl)phthalate 4 J,B	1.0			Ag - ND	Cr - 28.4 N	NA	NA
											Hg - ND			
											Pb - ND			
											Se - ND			

ND - Not Detected

NA - Not Analyzed

#### Organic Parameters

J - The value reported is an estimated concentration. This is used when the compound is detected at an amount less than the reporting limit.

B - The analyte is found in the associated blank as well as in the sample.

#### Inorganic Parameters

N - Spiked sample recovery not within control limits.

B - Reported value is less than Reporting limit but greater than the IDL.

S - Reported value was determined by the Method of Standard Additions

• - Duplicate analysis not within control limits.

W - Post digestion spike for Furnace AA analysis out of control limits (85-115%) while sample absorbance is less than 50% of spike absorbance.

Source: ES, 1990b

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**TABLE 5-6K: FTA3 GROUNDWATER QUARTERLY RESULTS**

8240-VOLATILE ORGANICS (ug/L)		2nd	Quarter 3rd	4th	Mean	Std. Dev.
FT3-002-MW	Ethylbenzene	1 J	82	5 U	27.83	46.91
	Xylenes	5 U	21	5 U	7.33	11.84
FT3-06I-MW	Benzene	5.6	6.6	10	7.40	2.31
	1,2-Dichloroethene (total)	1.6 J	5 U	1.5 J	1.20	0.56

8270-SEMIVOLATILE ORGANICS (ug/L)		2nd	Quarter 3rd	4th	Mean	Std. Dev.
FT3-001-MW	Phenol	4 J	5.6 J	10 U	3.37	2.61
FT3-002-MW	Napthlene	10 U	7.7 J	10 U	2.90	4.16
	Pentachlorophenol	50 U	12 J	50 U	5.67	5.48
FT3-003-MW	N-Nitrosodiphenylamine	100 U	1.2 J	10 U	2.23	2.42
	Phenol	100 U	2.7 J	10 U	2.73	2.25
FT3-004-MW	Phenol	10 U	1.1 J	10 U	0.70	0.35
FT3-005-MW	Phenol	10 U	1.5 J	10 U	0.83	0.58
FT3-006-MW	Methapyrilene	1.3 J	10 U	50 U	1.43	1.01
	Phenol	1.9 J	3.9 J	50 U	2.77	1.03
FT3-06I-MW	2-Acetylaminofluorene	2.1 J	500 U	100 U	10.70	12.47
	7,12-Dimethylbenz(a)anthracene	1.8 J	50 U	10 U	1.60	1.01
	3-Methylcholanthrene	2.2 J	50 U	10 U	1.73	1.08
	Pentachlorophenol	8.1 J	250 U	50 U	7.70	5.01

METALS (mg/L)		2nd Quarter		3rd Quarter		4th Quarter	
		Total	Dissolved	Total	Dissolved	Total	Dissolved
FT3-001-MW	Arsenic	0.0056	0.005 U	0.0078	0.005 U	0.012	0.005 U
	Barium	0.48	0.4	0.6	0.41	0.72	0.41
	Beryllium	0.002 U	0.002 U	0.0011 J	0.002 U	0.002 U	0.002 U
	Calcium	141	133	162	140	165	142
	Chromium	0.0075 J	0.01 U	0.01	0.01 U	0.022	0.01 U
	Cobalt	0.0049 J	0.01 U	0.0084 J	0.01 U	0.017	0.01 U
	Copper	0.019 J	0.02 U	0.015 J	0.02 U	0.028	0.02 U
	Iron	13.4	8.7	20.6	8	28.1	5.4
	Lead	0.0049 J	0.005 U	0.0071	0.005 U	0.014	0.01 U
	Magnesium	44	40.5	48.1	42.8	48.5	43.7
	Manganese	0.88	0.4	1.5	0.41	2.2	0.41
	Nickel	0.014 J	0.04 U	0.028 J	0.04 U	0.06	0.04 U
	Potassium	6.6	5.1	6.8	5.7	7.9	6.4
	Silver	0.0036 J	0.0029 J	0.01 U	0.01 U	0.01 U	0.01 U
	Sodium	24.5	21.9	23.8	22.4	22.8	24
	Vanadium	0.0073 J	0.01 U	0.018	0.01 U	0.03	0.01 U
	Zinc	0.031	0.0022 J	0.047	0.0095 J	0.094	0.018 J

B = Analyte detected in blank    U = Nondetected    J = Estimated value  
R = Rejected value    Q = Value may not be site-related

Source: Woodward-Clyde, 1992b

TABLE 5-6K: FTA3 GROUNDWATER QUARTERLY RESULTS

METALS (mg/L)		2nd Quarter		3rd Quarter		4th Quarter	
		Total	Dissolved	Total	Dissolved	Total	Dissolved
FT3-002-MW	Arsenic	0.017	0.0097	0.01	0.01	0.0099	0.0088 J
	Barium	0.66	0.41	0.93	0.73	0.81	0.58
	Beryllium	0.002 U	0.002 U	0.0015 J	0.002 U	0.002 U	0.002 U
	Calcium	343	268	289	271	284	269
	Chromium	0.021	0.01 U	0.018	0.01 U	0.011	0.01 U
	Cobalt	0.014	0.01 U	0.018	0.011	0.014	0.007 J
	Copper	0.026	0.02 U	0.023	0.02	0.029	0.02 U
	Iron	17	2.2	20.4	7.4	19.9	6.9
	Lead	0.018	0.01 U	0.0069	0.005 U	0.0072	0.005 U
	Magnesium	77.8	47.7	63.6	56.1	60.1	48.8
	Manganese	3.7	2.8	4.6	4.5	4.2	3.5
	Mercury	0.000073 J	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
	Nickel	0.035 J	0.0092 J	0.037 J	0.014 J	0.028 J	0.011 J
	Potassium	13.8	7	7	5.2	8.4	5.9
	Silver	0.01 U	0.0055 J	0.01 U	0.01 U	0.01 U	0.0062 J
	Sodium	28.5	19.5	21.1	20.6	22.1	19.9
	Tin	0.1 U	0.034 J	0.01 U	0.1 U	0.1 U	0.1 U
	Vanadium	0.03	0.01 U	0.024	0.01 U	0.019	0.01 U
	Zinc	0.085	0.005 J	0.074	0.015 J	0.055	0.0035 J
FT3-003-MW	Arsenic	0.16	0.11	0.084	0.14	0.18	0.12
	Barium	0.67	0.38	1	0.55	0.57	0.36
	Beryllium	0.002 U	0.002 U	0.0018 J	0.002 U	0.002 U	0.002 U
	Calcium	176	144	218	203	150	134
	Chromium	0.013	0.01 U	0.026	0.01 U	0.015	0.01 U
	Cobalt	0.0084 J	0.01 U	0.014	0.01 U	0.0051 J	0.01 U
	Copper	0.031	0.02 U	0.035	0.02 U	0.024	0.02 U
	Iron	60.5	34	78.9	46.2	49.6	27.2
	Lead	0.022	0.005 U	0.023	0.005 U	0.012	0.005 U
	Magnesium	46	33.6	58.9	49.2	39.2	31.5
	Manganese	1.4	0.88	2.3	1.8	1	0.78
	Nickel	0.025 J	0.04 U	0.044	0.0038 J	0.025 J	0.04 U
	Potassium	9.4	5.7	9.2	6.3	9.6	6.9
	Silver	0.0024 J	0.0033 J	0.01 U	0.01 U	0.01 U	0.0064 J
	Sodium	12.2	10	13	12.1	12.4	11.9
	Tin	0.52	0.024 J	0.1 U	0.1 U	0.1 U	0.1 U
	Vanadium	0.03	0.01 U	0.042	0.01 U	0.021	0.01 U
	Zinc	0.078	0.0016 J	0.11	0.0085 J	0.063	0.0035 J

B = Analyte detected in blank    U = Nondetected    J = Estimated value

R = Rejected value    Q = Value may not be site-related

Source: Woodward-Clyde, 1992b

89MC208H/0005

B-22

dml: FT3\_HIT.XLS

TABLE 5-6K: FTA3 GROUNDWATER QUARTERLY RESULTS

METALS (mg/L)		2nd Quarter		3rd Quarter		4th Quarter	
		Total	Dissolved	Total	Dissolved	Total	Dissolved
FT3-004-MW	Arsenic	0.0078	0.005 U	0.0039 J	0.005 U	0.005 U	0.005 U
	Barium	0.24	0.16	0.26	0.15	0.17	0.16
	Calcium	116	113	103	100	98.2	101
	Chromium	0.01 U	0.0071 J	0.011 J	0.01 U	0.01 U	0.01 U
	Cobalt	0.0051 J	0.01 U	0.02 U	0.01 U	0.01 U	0.01 U
	Copper	0.012 J	0.02 U	0.04 U	0.02 U	0.006 J	0.02 U
	Iron	8.8	0.1 U	9.7	0.1 U	1.6	0.1 U
	Lead	0.0075	0.005 U	0.0062	0.005 U	0.005 U	0.0037 J
	Magnesium	23.9	21.6	19	16.8	16.3	16.7
	Manganese	0.57	0.19	0.28	0.01 U	0.046	0.01 U
	Mercury	0.000073 J	0.00011 J	0.0002 U	0.0002 U	0.0002 U	0.0002 U
	Nickel	0.012 J	0.04 U	0.014 J	0.04 U	0.0072 J	0.04 U
	Potassium	5.5	3.8 J	3.1 J	2.3 J	2.5 J	3 J
	Selenium	0.02 U	0.01 U	0.01 U	0.003 J	0.01 U	0.01 U
	Silver	0.0029 J	0.0025 J	0.02 U	0.01 U	0.01 U	0.01 U
	Sodium	9.7	8.2	4.7 J	4.6 J	4.5 J	5
	Vanadium	0.014	0.01 U	0.015 J	0.01 U	0.01 U	0.01 U
	Zinc	0.034	0.0033 J	0.046	0.0043 J	0.022	0.011 J
FT3-005-MW	Arsenic	0.014	0.012	0.019	0.0079	0.016	0.005 U
	Barium	0.23	0.21	0.47	0.21	0.34	0.24
	Beryllium	0.002 U	0.002 U	0.0016 J	0.002 U	0.002 U	0.002 U
	Calcium	130	130	155	133	143	135
	Chromium	0.01 U	0.0066 J	0.019	0.01 U	0.01 U	0.01 U
	Cobalt	0.0045 J	0.01 U	0.011	0.01 U	0.01 U	0.01 U
	Copper	0.02 U	0.02 U	0.023	0.02 U	0.01 J	0.02 U
	Iron	3.3	1.5	28.2	0.91	12.8	1.2
	Lead	0.005 U	0.005 U	0.017	0.005 U	0.0054	0.005 U
	Magnesium	24.4	24.5	30.5	24.2	33.3	26.6
	Manganese	0.47	0.45	0.82	0.37	1.4	1.1
	Nickel	0.04 U	0.04 U	0.031 J	0.04 U	0.014 J	0.04 U
	Potassium	5.6	4.4 J	6.6	4.9 J	6.9	5
	Silver	0.01 U	0.0033 J	0.01 U	0.01 U	0.01 U	0.0054 J
	Sodium	8.9	7	7.9	7.2	7.9	7.6
	Vanadium	0.01 U	0.01 U	0.035	0.01 U	0.012	0.01
	Zinc	0.02 U	0.0021 J	0.087	0.01 J	0.037	0.0047 J

B = Analyte detected in blank    U = Nondetected    J = Estimated value

R = Rejected value    Q = Value may not be site-related

**TABLE 5-6K: FTA3 GROUNDWATER QUARTERLY RESULTS**

METALS (mg/L)		2nd Quarter		3rd Quarter		4th Quarter	
		Total	Dissolved	Total	Dissolved	Total	Dissolved
FT3-006-MW	Arsenic	0.049	0.017	0.025	0.013	0.021	0.014
	Barium	0.7	0.28	0.58	0.28	0.73	0.32
	Beryllium	0.002 U	0.002 U	0.0016 J	0.002 U	0.002 U	0.002 U
	Calcium	176	144	182	161	190	170
	Chromium	0.036	0.01 U	0.032	0.01 U	0.045	0.01 U
	Cobalt	0.025	0.01 U	0.014	0.01 U	0.024	0.01 U
	Copper	0.064	0.02 U	0.031	0.02 U	0.057	0.02 U
	Iron	49.7	1.8	30.4	2	51	2.5
	Lead	0.043	0.005 U	0.015	0.005 U	0.028	0.0021 J
	Magnesium	51.7	36.8	46.5	37.4	55.9	45.9
	Manganese	3.1	2.3	2.3	1.9	3.4	2.8
	Mercury	0.00012 J	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
	Nickel	0.064	0.04 U	0.047	0.008 J	0.092	0.029 J
	Potassium	12.8	6.3	9.3	5.9	10.8	9
	Silver	0.0034 J	0.0039 J	0.01 U	0.01 U	0.01 U	0.01 U
	Sodium	11.6	10	10.4	9.6	11.3	12.8
	Vanadium	0.082	0.01 U	0.044	0.01 U	0.072	0.01 U
	Zinc	0.16	0.0037 J	0.099	0.0048 J	0.17	0.013 J
FT3-061-MW	Arsenic	0.02	0.016	0.022	0.02	0.02	0.018
	Barium	0.41	0.38	0.43	0.43	0.42	0.42
	Calcium	180	172	189	197	181	187
	Chromium	0.01 U	0.01 U	0.01 U	0.01 U	0.019	0.01 U
	Cobalt	0.0046 J	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
	Copper	0.0059 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
	Iron	8.1	7.2	8.9	8.6	10.6	8.5
	Lead	0.005 U	0.005 U	0.01 U	0.01 U	0.0041 J	0.005 U
	Magnesium	55.8	51	57.4	58.4	55	55.9
	Manganese	4.3	4.2	4.4	4.6	4.3	4.5
	Nickel	0.031 J	0.026 J	0.032 J	0.032 J	0.036 J	0.026 J
	Potassium	7.8	6.1	6.6	6.5	7.4	8.5
	Silver	0.0026 J	0.0036 J	0.01 U	0.01 U	0.01 U	0.01 U
	Sodium	16.5	14.5	15.6	15.4	15.9	17.6
	Tin	0.1 U	0.011 J	0.1 U	0.1 U	0.1 U	0.013 J
	Vanadium	0.01 U	0.01 U	0.01 U	0.01 U	0.0056 J	0.01 U
	Zinc	0.01 J	0.0027 J	0.016 J	0.012 J	0.035	0.005 J
GENERAL INORGANICS (mg/L)		Quarter					
		2nd	3rd	4th			
FT3-001-MW	Alkalinity, Total	552	552	565			
	Alkalinity, Bicarb	552	552	565			
	Chloride	3.2	4	3.5			
	Sulfate	37.3	41.3	37			
	Total Dissolved Solids	615	618	617			
FT3-002-MW	Alkalinity, Total	1040	966	954			
	Alkalinity, Bicarb	1040	966	954			
	Chloride	3 U	4.3	4.4			
	Sulfate	51.4	34.3	32.4			
	Total Dissolved Solids	1120	1070	1070			

B = Analyte detected in blank    U = Nondetected    J = Estimated value  
R = Rejected value    Q = Value may not be site-related

Source: Woodward-Clyde, 1992b

TABLE 5-6K: FTA3 GROUNDWATER QUARTERLY RESULTS

GENERAL INORGANICS (mg/L)		Quarter		
		2nd	3rd	4th
FT3-003-MW	Alkalinity, Total	566	667	500
	Alkalinity, Bicarb	566	667	500
	Chloride	7.2	13.1	12.8
	Sulfate	5 U	8.3	5 U
	Total Dissolved Solids	588	715	556
FT3-004-MW	Alkalinity, Total	367	297	301
	Alkalinity, Bicarb	367	297	301
	Chloride	3.3	4.2	3.9
	Sulfate	21	19.7	17.7
	Total Dissolved Solids	444	388	370
FT3-005-MW	Alkalinity, Total	439	429	449
	Alkalinity, Bicarb	439	429	449
	Chloride	3 U	3	3.2
	Nitrate plus Nitrite	0.11	0.1 U	0.1 U
	Sulfate	15.6	19.7	15.1
FT3-006-MW	Total Dissolved Solids	499	495	502
	Alkalinity, Total	536	502	580
	Alkalinity, Bicarb	536	502	580
	Chloride	13.5	14.3	31.6
	Sulfate	24.4	27.4	15.9
FT3-06I-MW	Total Dissolved Solids	614	599	680
	Alkalinity, Total	677	664	670
	Alkalinity, Bicarb	677	664	670
	Chloride	34.5	36.9	34.2
	Sulfate	8.2	8	7.1
FT3-06I-MW	Total Dissolved Solids	812	853	820

B = Analyte detected in blank    U = Nondetected    J = Estimated value

R = Rejected value    Q = Value may not be site-related



**TABLE 5-6H: HF6 GROUNDWATER QUARTERLY RESULTS**

8240-VOLATILE ORGANICS (ug/L)		Quarter				Mean	Std. Dev.
		1st	2nd	3rd	4th		
HF6-004-MW	Benzene	14 J	8.3	6.8	11	10.03	3.17
	Ethylbenzene	270	44	34	200	137.00	116.78
	Xylenes (total)	77	5 U	5 U	49	31.75	37.85
8270-SEMI-VOLATILE ORGANICS (ug/L)		Quarter				Mean	Std. Dev.
		1st	2nd	3rd	4th		
HF6-002-MW	Pentachlorophenol	3.8 J	50 U	50 U	50 U	3.16	1.23
METALS (mg/L)		1st Quarter	2nd Quarter		3rd Quarter		4th Quarter
		Total	Total	Dissolved	Total	Dissolved	Total Dissolved
HF6-001-MW	Arsenic	0.025	0.05	0.019	0.041	0.02	0.039 0.015
	Barium	0.34	0.33	0.28	0.32	0.29	0.34 0.3
	Calcium	139	146	140	134	138	138 140
	Copper	0.019 J	0.0074 J	0.02 U	0.028	0.02 U	0.032 0.02 U
	Iron	17.6 J	19.8	11.7	16.1	10	18.4 10.4
	Lead	0.005 U	0.01 U	0.005 U	0.01 U	0.01 U	0.005 U 0.01 U
	Magnesium	44.2	49.3	43.1	43.3	43.8	44.8 43.9
	Manganese	R	2.4	2.3	2.8	2.8	2.9 3
	Mercury	0.0002 U	0.000084 J	0.000051 J	0.0002 U	0.0002 U	0.0002 U 0.0002 U
	Nickel	0.011 J	0.0049 J	0.04 U	0.04 U	0.04 U	0.0089 J 0.04 U
	Potassium	6.1	9.4	6	5.4	5.7	6.7 5.5
	Selenium	R	0.01 U	0.02 U	0.01 U	0.02 U	0.0028 J 0.01 U
	Silver	0.01 U	0.01 U	0.0022 J	0.01 U	0.01 U	0.01 U 0.0078 J
	Sodium	27.9	41.2	30.9	30	29.9	32.1 33.1
	Thallium	0.0017 J	0.005 U	0.01 U	0.01 U	0.01 U	0.02 U 0.005 U
	Vanadium	0.0099 J	0.0045 J	0.01 U	0.01 U	0.01 U	0.0062 J 0.01 U
	Zinc	0.048	0.021	0.002 J	0.027	0.0093 J	0.027 0.0059 J
HF6-002-MW	Arsenic	0.044	0.05	0.047	0.038	0.036	0.049 0.024
	Barium	0.48	0.43	0.41	0.47	0.45	0.57 0.43
	Calcium	179	170	166	180	180	188 180
	Cobalt	0.0061 J	0.0081 J	0.01 U	0.0088 J	0.0064 J	0.014 0.0068 J
	Copper	0.012 J	0.0089 J	0.02 U	0.027	0.02 U	0.022 0.02 U
	Iron	17.1	14.6	11.7	15.2	12.4	23.3 9
	Lead	0.005 U	0.0048 J	0.005 U	0.005 U	0.005 U	0.005 U 0.005 U
	Magnesium	35.6	37.9	32.9	36.7	36.3	39.6 35.4
	Manganese	1.6	1.8	1.7	1.9	1.9	2 1.9
	Mercury	0.0002 U	0.0002 J	0.000084 J	0.0002 U	0.0002 U	0.0002 U 0.0002 U
	Nickel	0.017 J	0.021 J	0.012 J	0.012 J	0.0069 J	0.04 0.015 J
	Potassium	6.7	10.2	6.8	6.5	6.3	9.2 7.7
	Silver	0.01 U	0.01 U	0.004 J	0.01 U	0.01 U	0.01 U 0.0079 J
	Sodium	18.8	30	22.9	24.2	24.4	27.5 29.5
	Vanadium	0.0078 J	0.0056 J	0.01 U	0.01 U	0.01 U	0.015 0.01 U
	Zinc	0.04	0.023	0.0046 J	0.03	0.0062 J	0.052 0.0046 J

B = Analyte detected in blank    U = Nondetected    J = Estimated value  
R = Rejected value    Q = Value may not be site-related

TABLE 5-6H: HF6 GROUNDWATER QUARTERLY RESULTS

METALS (mg/L)		1st Quarter	2nd Quarter		3rd Quarter		4th Quarter	
		Total	Total	Dissolved	Total	Dissolved	Total	Dissolved
HF6-003-MW	Arsenic	0.036	0.034	0.013	0.026	0.01	0.057	0.014 J
	Barium	0.31	0.28	0.23	0.27	0.23	0.32	0.24
	Calcium	133	176	166	152	147	135	131
	Chromium	0.01 U	0.012	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
	Cobalt	0.01 U	0.0046 J	0.01 U	0.0045 J	0.0048 J	0.01 U	0.01 U
	Copper	0.012 J	0.0074 J	0.02 U	0.097	0.02 U	0.022	0.02 U
	Iron	18.6	10.2	3.1	11.1	4.9	22.6	7.3
	Lead	0.02 U	0.005 U	0.005 U	0.01 U	0.004 J	0.01 U	0.01 U
	Magnesium	35.2	42.7	36.7	38	35.9	35.7	33.9
	Manganese	1.3	1.1	1	1.2	1.2	1.3	1.3
	Nickel	0.012 J	0.0089 J	0.04 U	0.02 J	0.04 U	0.012 J	0.04 U
	Potassium	5.6	8.3	5.5	5.8	5.4	6.5	5.5
	Selenium	0.01 U	0.0046 J	0.01 UJ	0.01 UJ	0.01 U	0.01 U	0.01 U
	Silver	0.01 U	0.003 J	0.0028 J	R	0.01 U	0.01 U	0.0058 J
	Sodium	13	20.8	16.1	15.8	14.8	16.6	17.1
	Vanadium	0.0099 J	0.01 U	0.01 U	0.01 U	0.01 U	0.0051 J	0.01 U
	Zinc	0.044	0.018 J	0.0036 J	0.037	0.0094 J	0.028	0.0052 J
HF6-004-MW	Arsenic	0.038	0.043	0.033	0.03	0.027	0.012	0.023 J
	Barium	1.4	0.64	0.42	0.66	0.49	1.1	0.46
	Beryllium	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.0017 J	0.002 U
	Calcium	181	136	117	152	144	176	123
	Chromium	0.028	0.015	0.01 U	0.013	0.01 U	0.03	0.01 U
	Cobalt	0.014	0.009 J	0.01 U	0.012	0.01 U	0.022	0.01 U
	Copper	0.031	0.021	0.02 U	0.04	0.02 U	0.048	0.02 U
	Iron	46.8	27	9.2	26.9	7.8	56	7
	Lead	0.028	0.014	0.005 U	0.0088	0.005 U	0.026	0.005 U
	Magnesium	52	36.9	27.5	37.5	33.6	49.5	28.3
	Manganese	2.3	2.4	2	2.4	2.3	2.9	2.2
	Mercury	0.0002 U	0.000051 J	0.000062 J	0.0002 U	0.0002 U	0.0002 U	0.0002 U
	Nickel	0.051	0.027 J	0.0055 J	0.04 U	0.04 U	0.059	0.0055 J
	Potassium	8.2	9.5	4.8 J	6.2	5	10.4	4.4 J
	Silver	0.01 U	0.01 U	0.0022 J	0.01 U	0.01 U	0.01 U	0.0071 J
	Sodium	10.6	17.2	11.8	13.1	12.9	11.8	10.1
	Tin	0.03 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
	Vanadium	0.05	0.021	0.01 U	0.022	0.01 U	0.062	0.01 U
	Zinc	0.17	0.068	0.0048 J	0.072	0.015 J	0.17	0.01 J

## GENERAL INORGANICS (mg/L)

		Quarter			
		1st	2nd	3rd	4th
HF6-001-MW	Alkalinity, Total	520	593	539	548
	Alkalinity, Bicarb	520	593	539	548
	Chloride	3.5	3 U	3.3	3.5
	Sulfate	55.3	59	61.9	63
	Total Dissolved Solids	634	664	602	643
HF6-002-MW	Alkalinity, Total	524	579	604	606
	Alkalinity, Bicarb	524	579	604	606
	Chloride	11.7	11.1	9.2	8.5
	Sulfate	57.3	79.6	70.8	46.4
	Total Dissolved Solids	642	719	747	701

B = Analyte detected in blank    U = Nondetected    J = Estimated value  
 R = Rejected value    Q = Value may not be site-related

Source: Woodward-Clyde, 1992b

**TABLE 5-6H: HF6 GROUNDWATER QUARTERLY RESULTS**

GENERAL INORGANICS (mg/L)		Quarter			
		1st	2nd	3rd	4th
HF6-003-MW	Alkalinity, Total	456	580	505	449
	Alkalinity, Bicarb	456	580	505	449
	Chloride	4.4	3.9	4.9	5.3
	Sulfate	44.8	62.4	54.9	43.6
	Total Dissolved Solids	529	676	604	543
HF6-004-MW	Alkalinity, Total	349	443	511	435
	Alkalinity, Bicarb	349	443	511	435
	Chloride	6.2	6.2	6.2	7.3
	Sulfate	5 U	5 U	6.8	5 U
	Total Dissolved Solids	466	540	617	527

B = Analyte detected in blank    U = Nondetected    J = Estimated value

R = Rejected value    Q = Value may not be site-related

Source: Woodward-Clyde, 1992b